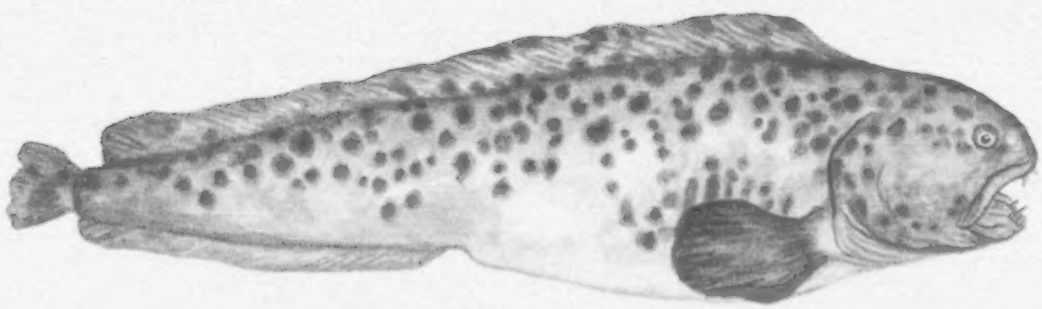
COSEWIC
Assessment and Status Report

on the

Spotted Wolffish
Anarhichas minor

in Canada



THREATENED
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
Spotted Wolffish

Scientific name
Anarhichas minor

Status
Threatened

Reason for designation
This species underwent strong declines from the late 1970s until the mid-1990s, but since then there has been some recovery over most of its Canadian range. This is indicated by both increases in abundance and area of occupancy. These increases parallel a reduction in bottom fisheries that had a high incidental catch of this species, as well as introduction of recovery measures including mandatory release. While these recent increases are encouraging, the species is still at low levels compared with the beginning of the research surveys.

Occurrence
Arctic Ocean, Atlantic Ocean

Status history
Designated Threatened in May 2001. Status re-examined and confirmed in November 2012.

COSEWIC
Executive Summary

Spotted Wolffish
Anarhichas minor

Wildlife Species Description and Significance

The Spotted Wolffish is a fish in the family Anarhichadidae. It gets its name from its large conical teeth. It is an elongate fish with a large head and rounded snout. It is yellowish or greyish brown to dark brown with numerous dark spots on its body. It has a long dorsal fin and no pelvic fins.

There are no indications of population structure that can be used to geographically distinguish Spotted Wolffish in Canada. This species is therefore treated as a single designatable unit in Canadian waters.

The Spotted Wolffish was of commercial interest in the 1990s, but the absence of sufficient concentrations has prevented a directed commercial fishery for this species. Prior to the ban on landing this species because of its listing in 2001 under Canada's *Species at Risk Act* (SARA), these fish were caught in mixed fisheries or as bycatch in other fisheries, including Greenland Halibut (*Rheinhardtius hippoglossoides*), Atlantic Cod (*Gadus morhua*) and Yellowtail Flounder (*Limanda ferruginea*).

Distribution

The Spotted Wolffish is found on both sides of the North Atlantic and in the Arctic. In Canadian waters, it is distributed from the Canadian portion of the Gulf of Maine to western Greenland, including the Scotian Shelf, Grand Banks, Gulf of St. Lawrence, northeastern Newfoundland, and the Labrador Sea. It is most abundant off northeastern Newfoundland and on the Labrador Shelf.

Habitat

The habitat requirements of the Spotted Wolffish are poorly known, including spawning, nursery and foraging grounds. It is believed that the eggs are deposited on the bottom, the larvae are pelagic and the juveniles and adults occupy bottom waters. The fish typically occupy depths between 200 and 750 m on the continental shelf or in deep trenches.

Biology

The length at which 50% of females reach sexual maturity is 75-80 cm. The age at which 50% of the population reaches sexual maturity is believed to be roughly 5.5 years, based on samples collected several decades ago. The generation time is estimated to be 10.5 years. Fertilization is internal and mating probably occurs in the summer. The fish spawn multiple times through their lives and produce relatively few eggs, which have a long incubation period. The larvae hatch at a length of over 20 mm and remain near the sea floor until the yolk sac is absorbed. Growth is believed to be rapid in the first few years of life, but slows considerably as the fish mature. The fish undertake only limited movements and no dispersal of the eggs is possible because they are deposited on the substrate. However, larvae are found in the upper water column, which allows for dispersal. Spotted Wolffish feed primarily on echinoderms. Juveniles have been found in the stomachs of seals and fish such as Atlantic Cod and Atlantic Halibut (*Hippoglossus hippoglossus*).

Population Sizes and Trends

Research trawl surveys over a large portion of the range of Spotted Wolffish in Canada have been conducted by Fisheries and Oceans Canada (DFO) for a number of years. The number of Spotted Wolffish in Canadian waters is believed to exceed 5 million and the number of mature individuals is believed to exceed 0.59 million.

The abundance of Spotted Wolffish in the central part of its range declined considerably from the late 1970s to the mid-1990s. However, since 1996, there has been an upward trend. In fall research trawl surveys in the waters off Newfoundland and the Labrador Shelf, abundance indices of all ages rose from 1.01 million in 1996 to 7.07 million in 2008, followed by a decline to 3.97 million in 2009. A similar pattern has been observed in the spring research trawl surveys since the mid-1990s.

In the rest of its Canadian range, Spotted Wolffish abundance is relatively low. On the Scotian Shelf, the species has been caught in only 22 of 7,200 research tows since 1970. A similar situation exists in the northern part of its Canadian range, where available data and catch rates are insufficient to establish the status of the species. In the Gulf of St. Lawrence, Spotted Wolffish are rarely caught in surveys. An index of abundance varied from 0 to 0.73 million from 1990 to 2009, with an increasing trend.

Outside of Canadian waters, in the Gulf of Maine, the Spotted Wolffish is at the limit of its range and is rare. Off western Greenland, its population is estimated at roughly 1 million. On the Flemish Cap, abundance was estimated at over 2.6 million in 2006. Fish off Greenland and on the Flemish Cap could provide a source of immigration to Canadian waters as their numbers are high relative to population estimates for most regions of Canada. However, any rescue effect would be possible only through the larval stage as adults are fairly sedentary.

Threats and Limiting Factors

Commercial fishing (mainly bycatch) has been the main potential threat to the Spotted Wolffish. While catches were relatively high in the 1970s, they declined considerably in the 1990s in Canadian waters. Fishing intensity is now much lower due to the closure of several groundfish fisheries and there is a ban on landing this species, which was designated as Threatened under the *Species at Risk Act* (SARA) in 2001. There is also bycatch outside Canadian waters. Climate change may also affect their distribution and abundance.

Protection, Status and Ranks

The Spotted Wolffish was first designated as Threatened by COSEWIC in 2001, the status was confirmed in 2012 and the species and has been protected under the federal *Species at Risk Act* (SARA) since 2003. It is also listed as likely to be designated threatened or vulnerable under Quebec's *Act Respecting Threatened or Vulnerable Species* (Loi sur les espèces menacées ou vulnérables; R.S.Q., c E-12.01). Some areas are currently closed to bottom-trawl fishing, and Canada's small network of marine protected areas may protect a very small segment of the population.

TECHNICAL SUMMARY

Anarhichas minor
Spotted Wolffish Loup tacheté
Range of occurrence in Canada: Eastern Arctic Ocean and the Atlantic Ocean (including the Scotian Shelf, Grand Banks, Gulf of St. Lawrence, northeastern Newfoundland, and the Labrador Sea)

Demographic Information

Generation time (approximate)	10.5 years
Is there a continuing decline in the number of mature individuals?	No
Estimated percent of continuing decline in the total number of mature individuals within 5 years or 2 generations	N/A
Estimated percent change in the total number of mature individuals over the last 10 years or 3 generations. This overall rate of decline is an approximation. Strong declines from the late 1970s until the mid-1990s (1 generation). Four- to five-fold increases from very small numbers in many areas since then (1.3 generations), but numbers remain low compared to the start of the surveys.	Decline 75-80%
Percent change in the total number of mature individuals over the next 10 years, or 3 generations.	Unknown
Percent change in the total number of mature individuals over any 10 year or 3 generation period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and have they ceased?	Yes
Are there extreme fluctuations in the number of mature individuals?	Unknown

Extent and occupancy information

Estimated extent of occurrence within Canada's extent of jurisdiction **2 525 000 km²** including major landmasses	1 664 000 km² excluding major landmasses
Index of area of occupancy (IAO) Based on a 2 × 2 grid value	14 000 km²
Is the total population severely fragmented?	No
Number of locations (as defined by threats) The main threats include bycatch mortality in diverse fisheries over a large region.	Multiple, but exact number unclear
Is there a continuing decline in the extent of occurrence?	No
Is there a continuing decline in the index of area of occupancy?	No
Is there a continuing decline in the number of populations?	No
Is there a continuing decline in the number of locations*?	No
Is there a continuing decline in the area, extent or quality of habitat?	No
Are there extreme fluctuations in the number of populations?	No
Are there extreme fluctuations in the number of locations	Probably not
Are there extreme fluctuations in the extent of occurrence?	No
Are there extreme fluctuations in the index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Canadian Range	>0.59 million

Quantitative Analysis

Probability of extinction in the wild is at least 20% within 20 years or 5 generations, or 10% within 100 years.	Not calculated

Threats (actual or imminent, to populations or habitats)

Bycatch in commercial fisheries, climate factors

Rescue Effect (immigration from outside Canada)

Status of outside populations	
Is immigration known or possible?	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Possible

Status History

Designated Threatened in May 2001. Status re-examined and confirmed in November 2012.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	A1b

Reasons for designation:

This species underwent strong declines from the late 1970s until the mid-1990s, but since then there has been some recovery over most of its Canadian range. This is indicated by both increases in abundance and area of occupancy. These increases parallel a reduction in bottom fisheries that had a high incidental catch of this species, as well as introduction of recovery measures including mandatory release. While these recent increases are encouraging, the species is still at low levels compared with the beginning of the research surveys.

Applicability of Criteria

Criterion A:

Time series are too short to calculate trends over three generations, and inferences are hampered by changes in gear used by survey vessels. Criterion A1b could be used because fisheries bycatch mortality is reversible and reasonably well understood and no longer causing declines. Long-term population trends probably meet Endangered under this criterion but the species is designated Special Concern because there have been increases in abundance and area of occupancy since the mid-1990s, in parallel with a reduction in the threat due to bycatch in fisheries.

Criterion B:

Does not apply because the extent of occurrence greatly exceeds 20,000 km² and the area of occupancy greatly exceeds 2,000 km².

Criterion C:

Does not apply because the number of mature individuals greatly exceeds 10,000.

Criterion D:

Does not apply because the number of mature individuals greatly exceeds 1,000 and the area of occupancy is very large.

Criterion E:

Not undertaken.

PREFACE

The Spotted Wolffish (*Anarhichas minor*) was assessed by COSEWIC in May 2001 and designated as Threatened, and it is on Schedule 1 of the *Species at Risk Act* (SARA) due primarily to a strong decline in abundance and a contraction of its range in the 1980s and 1990s.

This report updates the status of this species based on abundance and distribution data that have become available since the last assessment. Some new information on habitat and population structure has also been included.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Spotted Wolffish
Anarhichas minor

in Canada

2012

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Actinopterygii

Order: Perciformes

Family: Anarhichadidae

Scientific name: *Anarhichas minor* (Olafsen 1772)

Common names: English – Spotted Wolffish
Also: Catfish, Spotted Sea Cat, Spotted Sea Catfish, Spotted Wolf
French – Loup tacheté
Also: Blennie-loup tacheté (France)

Morphological Description

Fish of the family Anarhichadidae are large marine fish that derive their name from their large conical teeth. There are three species of wolffish in the Canadian Atlantic and adjacent Arctic: Spotted Wolffish (*Anarhichas minor*), which is the subject of this report, Atlantic Wolffish (*Anarhichas lupus*) and Northern Wolffish (*A. denticulatus*).

The Spotted Wolffish (Figure 1) is an elongate fish with a relatively large head, rounded snout, and large pectoral fins. In common with all wolffish, it has large prominent canine-like teeth in the front of its jaws and flattened, grinding (vomerine) teeth behind. It is yellowish or greyish brown to dark brown with numerous dark spots on its body and a long dorsal fin (Scott and Scott 1988). There are no pelvic fins. It is distinguished from other wolffish by the distinctive spotted pattern on its body. Additionally, its body musculature is firm and not jelly-like as in the Northern Wolffish, and the row of grinding vomerine[1] teeth reaches as far back as the rows of palatine teeth[2] (Kulka *et al.* 2007b).

[1] The vomer is a single, median bone that forms the inferior and posterior portion of the nasal septum.
[2] Palatine teeth are those that grow on the sides of the palate towards the centre of the jaw, rather than on the dental arch.

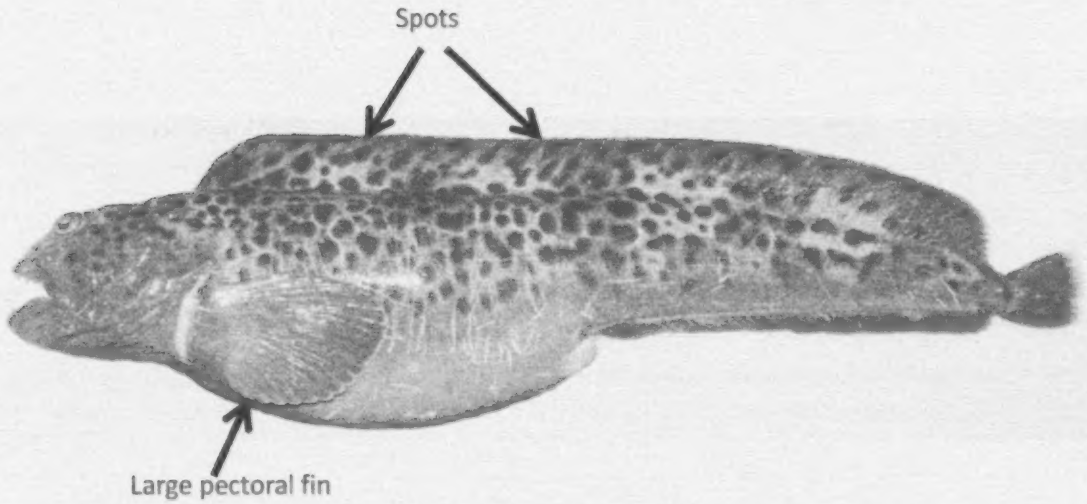


Figure 1. Spotted Wolffish (*Anarhichas minor*) and distinguishing morphological features. Photo credit: C. Nozères, Department of Fisheries and Oceans.

Population Spatial Structure and Variability

Dispersal by eggs is not possible because eggs are thought to be deposited on the substrate (O'Dea and Haedrich 2001) based on observations of the closely related Atlantic Wolffish. Adults are also considered sedentary (see "Dispersal and Migration"). However, wolffish larvae are found in the upper water column, which allows for dispersal. Little is currently known about the population structure of this species (Kulka *et al.* 2004).

Templeman (1986) conducted a comparative study of meristic characteristics in the northwest Atlantic, comparing vertebral numbers and dorsal fin-ray numbers of several Spotted Wolffish caught off Newfoundland, Labrador and western Greenland. No differences were observed between individuals from different regions.

Genetic differences between the three species of wolffish of the northwestern Atlantic were evaluated on the basis of their mitochondrial genomes (Johnstone *et al.* 2007, McCusker and Bentzen 2010), nuclear microsatellite markers (McCusker *et al.* 2008) and nuclear amplified fragment length polymorphisms (AFLP) (McCusker and Bentzen 2010a). These studies showed that the three wolffish species in the Atlantic are distinct from each other, with Spotted Wolffish more closely related to the Atlantic Wolffish than to the Northern Wolffish.

Imsland *et al.* (2008) analyzed genetic population structure of the Spotted Wolffish across the range of the species using allozyme and restriction fragment length polymorphism (RFLP) analysis of mitochondrial DNA (mtDNA). The results showed significant differentiation on trans-Atlantic scales. Differentiation was also observed between two samples collected from the same region of the Gulf of St. Lawrence at different times, a surprising result that may have been an artefact of inadvertent inclusion of two species of wolffish in one of the Gulf of St. Lawrence samples (Imsland *et al.* 2008).

McCusker and Bentzen (2011) used 10 microsatellite loci and 98 amplified fragment length polymorphism (AFLP) loci to examine population structure across the species range. Their samples did not allow examination of population structure within Atlantic Canadian waters, but showed very weak and, for the most part, statistically insignificant differentiation among locations separated by deep ocean basins and spatial scales greater than 1000 km.

Designatable Units

To date, there is no evidence to support the recognition of more than one designatable unit of Spotted Wolffish within Canadian waters; accordingly, the species is treated as a single DU in this report.

Special Significance

Spotted Wolffish was of commercial interest in the early 1990s. It can be filleted and sold fresh or frozen. The skin can also be tanned and marketed. However, a directed commercial fishery for this species is not possible due to a lack of sufficient concentrations of individuals. As a result, this species has little commercial value. Since 2003, it has been mandatory under the *Species at Risk Act* to release Spotted Wolffish catches due to the species' Threatened COSEWIC designation.

Spotted Wolffish are caught in mixed fisheries or incidentally as bycatch, mainly with Greenland Halibut, Atlantic Cod or Yellowtail Flounder (Kulka *et al.* 2007a). The largest landings were reported on the south coast of Newfoundland and in Nova Scotia.

The ecological role of the Spotted Wolffish is difficult to assess. The larvae and juveniles are believed to be subject to predation by several species of fish, but their relative importance in the diet of these species is unknown. Adults have few predators owing to their large size.

DISTRIBUTION

Global Range

The Spotted Wolffish is widely distributed on both sides of the North Atlantic and in the Arctic. In the northeastern Atlantic, it occurs from Greenland and Iceland to the coast of Norway (Figure 2). In the northwest Atlantic, it is found from Davis Strait to the Gulf of Maine. However, it is rare in the south on the Scotian Shelf and in United States waters. It is a cold-water species.

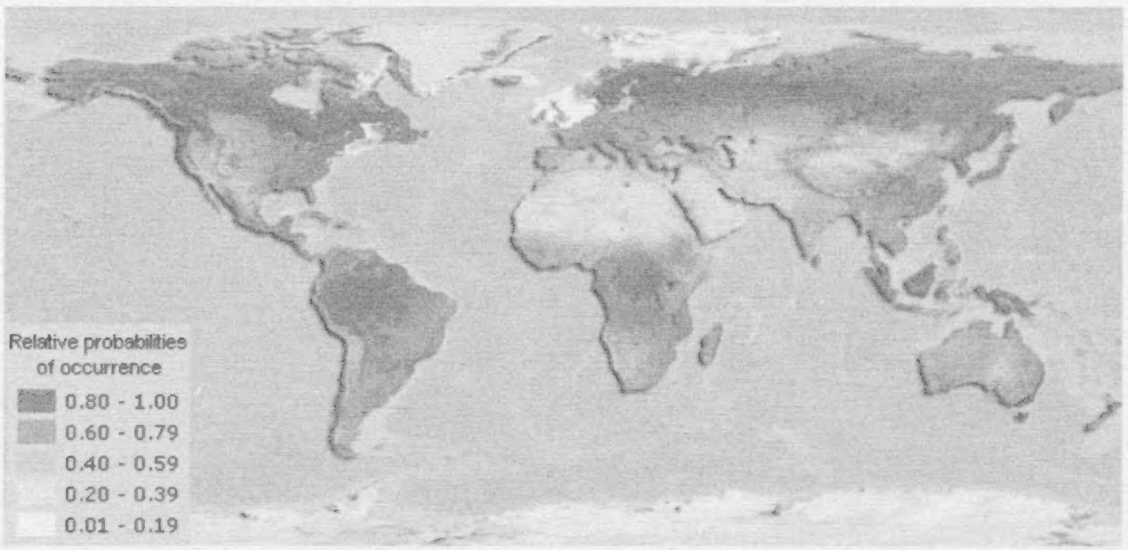


Figure 2. Potential global range of the Spotted Wolffish. Source: Kaschner *et al.* (2008).

Search Effort

Most information on the distribution of Spotted Wolffish comes from trawl surveys conducted by DFO (see "Sampling Effort and Methods"). These surveys do not cover certain habitats, such as at depths less than about 25 m, rocky areas (due to the high risk of gear damage) or deep waters in some areas.

In recent years, additional surveys in which Spotted Wolffish are likely to be caught are being conducted by DFO in collaboration with industry, such as the Groundfish Sentinel Program, which conducts mobile gear surveys (bottom trawl) and fixed gear surveys (longline and gill net), redfish surveys conducted in collaboration with the Groundfish Enterprise Allocation Council (GEAC), and Atlantic Halibut surveys.

Although the Canadian At-Sea Fisheries Observer Program (commercial fisheries) also includes data on wolffish bycatch and extends further north than DFO's research trawl surveys, the data are not directly comparable and are therefore not included here. Table 1 shows the main surveys used to determine distribution in Canadian waters. Figure 3 shows the locations of the areas mentioned in this report, and Figure 4 shows the NAFO Divisions.

Table 1. Information sources used to determine the distribution of Spotted Wolffish in Canadian waters.

Regions	Information source
Newfoundland & Labrador region (Labrador Shelf, northeastern and southern Newfoundland)	Department of Fisheries and Oceans Canada spring research trawl survey
	Department of Fisheries and Oceans Canada fall research trawl survey
Gulf of St. Lawrence	Department of Fisheries and Oceans Canada Northern Gulf research trawl survey
	Department of Fisheries and Oceans Canada Southern Gulf research trawl survey
	Sentinel Fisheries Program
Maritimes region (Scotian Shelf, Bay of Fundy, Gulf of Maine)	Department of Fisheries and Oceans Canada Maritimes summer research trawl survey

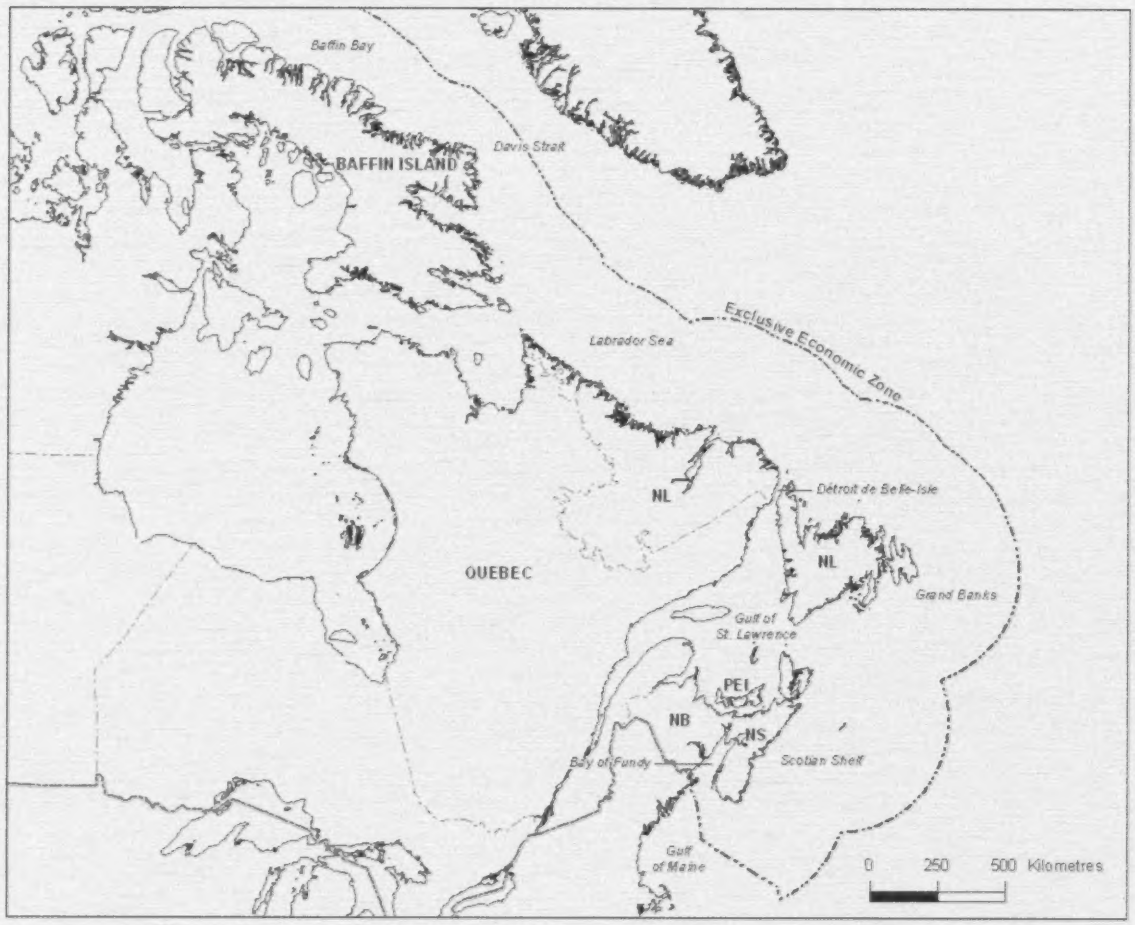


Figure 3. Map of geographic locations mentioned in the document.

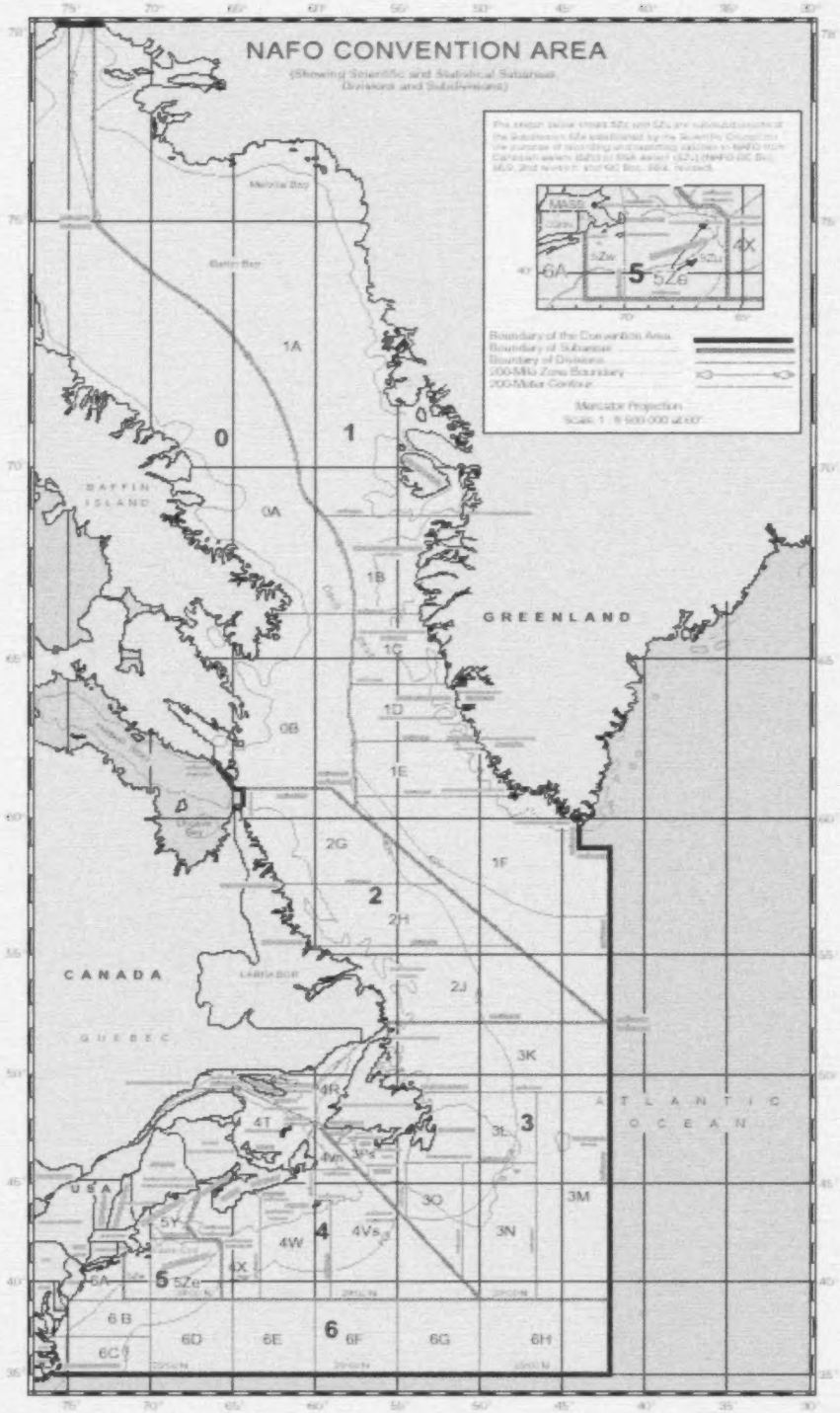


Figure 4. Northwest Atlantic Fisheries Organization (NAFO) Divisions and Subdivisions.

Canadian Range

In Canadian waters, the Spotted Wolffish occurs in Davis Strait, off Baffin Island, in the Labrador Sea, in the Gulf of St. Lawrence, off the east coast of Newfoundland, on the Grand Banks, and on the Scotian Shelf (Figure 5). The central part of its range is located on the Labrador Shelf and off northeastern Newfoundland (Kulka *et al.* 2007a).

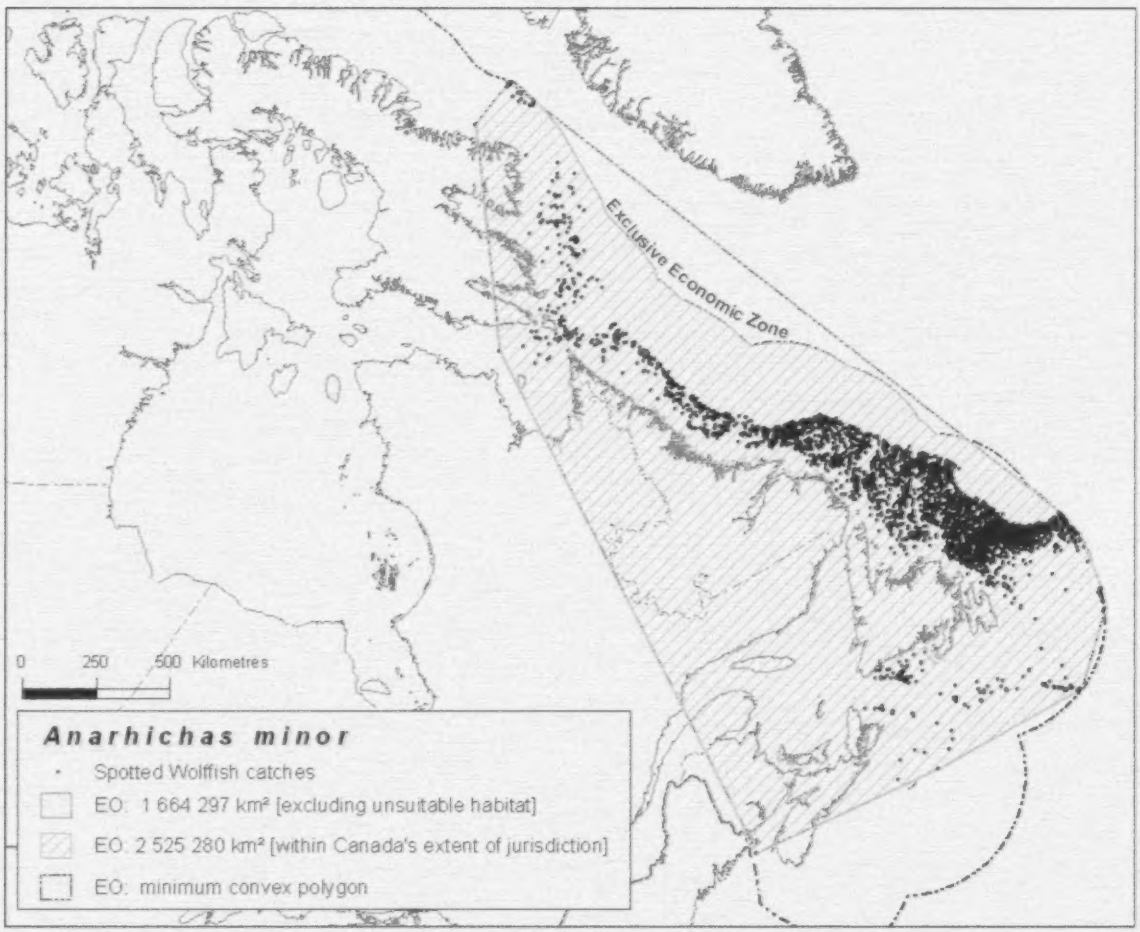

Exclusive Economic Zone
0 250 500 Kilometres
Anarhichas minor
Spotted Wolffish catches
EO: 1 664 297 km² [excluding unsuitable habitat]
EO: 2 525 280 km² [within Canada's extent of jurisdiction]
EO: minimum convex polygon

Figure 5. Extent of occurrence in Canada of Spotted Wolffish based on Department of Fisheries and Oceans Canada research trawl survey catches.

This species is most abundant in the deep waters (200-750 m) of the continental shelf, northeast of Newfoundland and on the Labrador Shelf. It is only observed occasionally in the Gulf of St. Lawrence (Dutil *et al.* 2010), on the Scotian Shelf, and in the Gulf of Maine (Simon *et al.* 2011). Its distribution in the Gulf of St. Lawrence is primarily in the northwest portion, particularly the Esquiman Channel and bordering areas (Dutil *et al.* 2010, Ouellet *et al.* 2010). They are rare in the southern Gulf.

Extent of Occurrence and Area of Occupancy

Distribution indices were calculated by the COSEWIC Secretariat. The extent of occurrence was determined by calculating the area of the minimum convex polygon encompassing areas well covered by research surveys in Canada (Figure 5). The extent of occurrence is estimated at 2.525×10^6 km^2 including some major landmasses, or 1.664×10^6 km^2 when these are excluded.

An index of area of occupancy was calculated using kriging based on a grid with a cell size of 2 km × 2 km of the entire area inhabited by Spotted Wolffish (Figure 6). This index is estimated at 14 000 km^2.

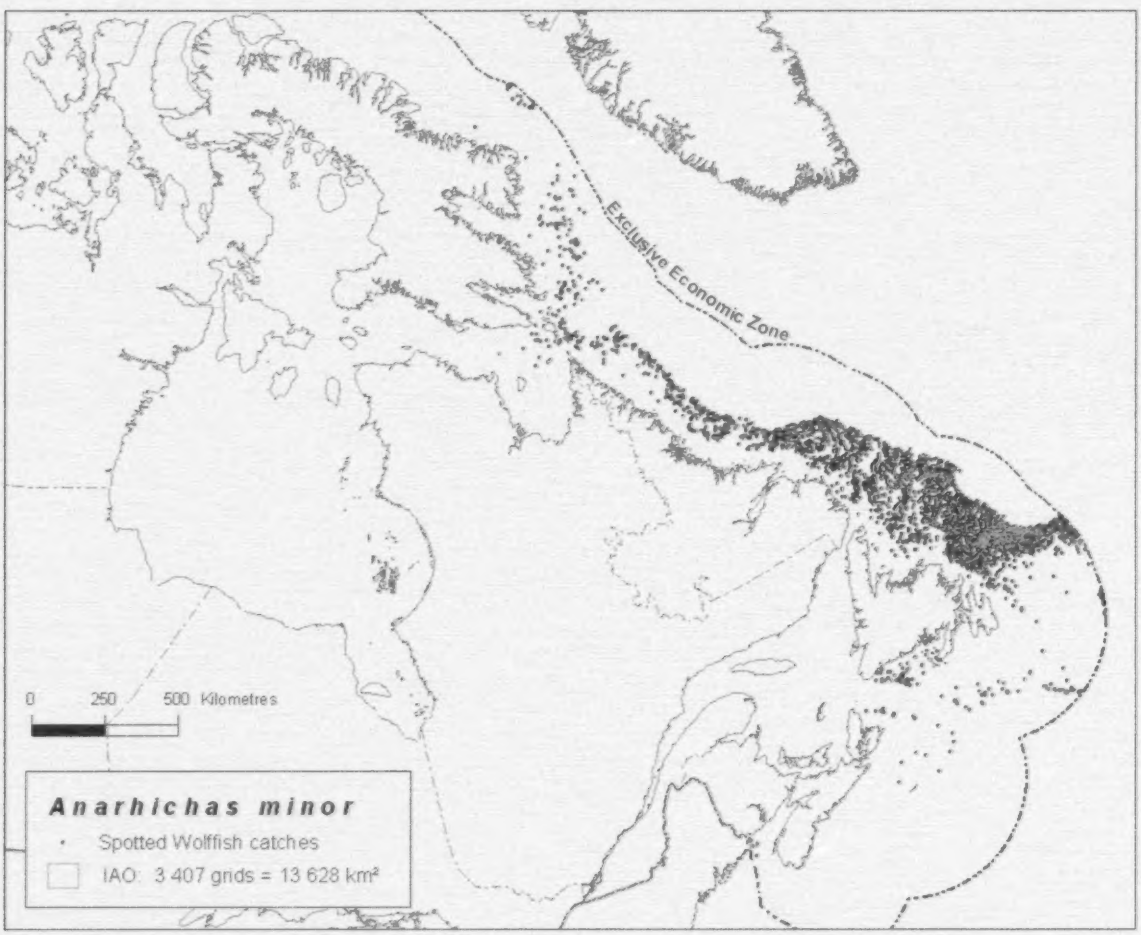


Figure 6. Index of area of occupancy in Canada of Spotted Wolffish based on Department of Fisheries and Oceans Canada research trawl survey catches.

The design-weighted area of occupancy (DWAO) index was calculated for the Newfoundland region:

$$A_t = \sum_{i=1}^{n} A_i I \quad \text{where } I = 1 \text{ if } Y_i > 0, \text{ 0 otherwise}$$

where n is the number of tows in the survey, Y_i is the number of individuals caught in tow i, and A_i is the area of the stratum fished by tow i divided by the number of sites fished in the stratum.

The Newfoundland and Labrador research trawl survey results show that the DWAO index for Spotted Wolffish declined significantly from the 1980s to the mid-1990s (Figure 7). However, the indices increased in both spring and fall surveys since the mid-1990s. It is important to bear in mind that due to gear changes, different data series values and trends cannot be compared directly.

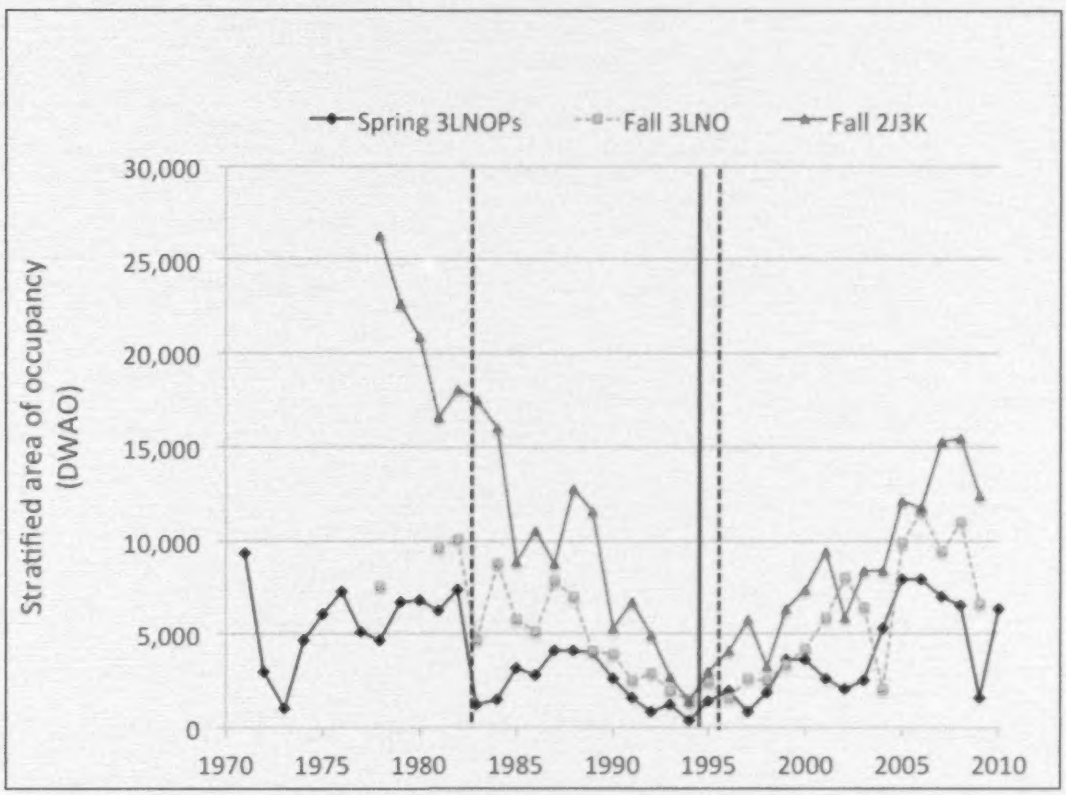


Figure 7. Index of area of occupancy (DWAO) of Spotted Wolffish on the Grand Banks (3LNO) off Newfoundland and in the Labrador Sea (2J3K) based on Newfoundland spring and fall research trawl surveys. The vertical dashed lines indicate gear changes for the spring survey and the vertical solid line indicates a gear change for the fall survey. Source: Simpson *et al.* (2011).

The DWAO index in Northern Gulf of St. Lawrence also shows an increasing trend in the 1990s (Figure 8). Fish were too rare in other areas to estimate DWAO.

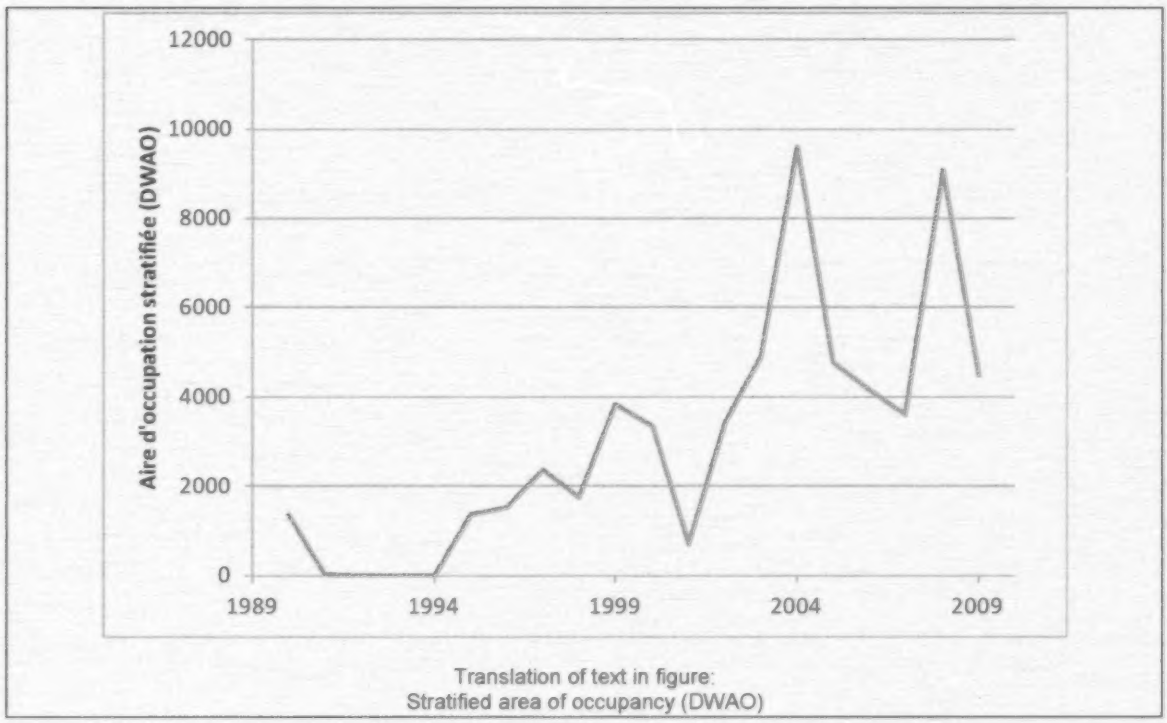


Figure 8. Index of area of occupancy (DWAO) of Spotted Wolffish in the Gulf of St. Lawrence (Div. 4RST) based on summer research trawl surveys. Source: Bourdage and Ouellet (in prep.).

HABITAT

Habitat Requirements

The habitat requirements of the Spotted Wolffish are poorly known. To date, no spawning, nursery or foraging grounds have been identified (Department of Fisheries and Oceans 2011). This species occupies different habitats depending on its life stage (see Kulka *et al.* 2007a). The eggs are probably deposited on the bottom, and newly hatched larvae are pelagic before settling in benthic environments at a length of 4-6 cm (Falk-Petersen and Hansen 2003). Juveniles and adults then occupy bottom. In laboratory experiments, juvenile Spotted Wolffish use shelters (Lachance *et al.* 2010).

The densest concentrations are found at 200-750 m, and there is evidence that they occupy shallower depths during periods of high abundance (Kulka *et al.* 2004). Higher densities can also occur at shallower depths (200-350 m) from June to November (Kulka *et al.* 2004). Little preference for any specific sediment type has been observed (Kulka *et al.* 2004). However, given the type of prey ingested (see section "Interspecific Interactions"), they probably forage in silty and sandy areas.

The Spotted Wolffish is a cool- to cold-water fish, with the highest densities at temperatures from 1.5-5°C (Kulka *et al.* 2004). On the Scotian Shelf it is found in temperatures ranging from 2 to 8 °C (Simon *et al.* 2011). Temperature is believed to limit their distribution and habitats (Kulka *et al.* 2004). Scotian Shelf waters are generally too warm for the species, hence their rarity there.

Habitat Trends

An episode of particularly cold water temperatures occurred in the late 1980s and early 1990s (Colbourne *et al.* 1997). Figure 9 shows the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) from 1950 to 2010 (Yashayaev and Greenan 2011). A positive index is associated with colder than usual conditions in the northern Labrador Sea. The index for the end of 1980 to mid-1990 showed higher values since 1950. The cold episode has been linked to changes in distributions of wolffish species (Kulka *et al.* 2004): shallower waters may have been abandoned in favour of deeper, warmer waters, though this is hypothetical. However, the decline in area of occupancy of Spotted Wolffish began at least 10 years before the cold episode.

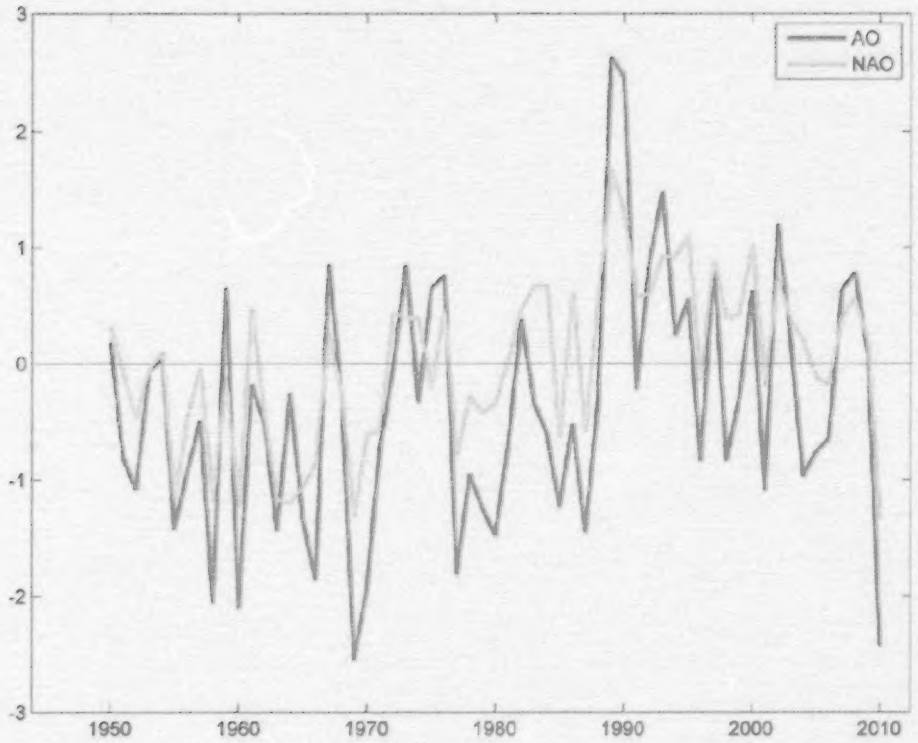


Figure 9. Winter Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) indices with 1950-2000 as base period. Data are for the Jan-Feb-Mar winter period. Source: Yashayaev and Greenan (2011).

Climate change will likely affect the habitat and distribution of the Spotted Wolffish since temperature seems to limit their distribution (Kulka *et al.* 2004). An increase in water temperatures in the northwestern Atlantic may result in a northward shift of marine cold-water fish species (Gucinski *et al.* 1990), as has been documented in the northeastern Atlantic (Perry *et al.* 2005).

BIOLOGY

Little information is available on the biology of the Spotted Wolffish, but deductions can be made from observations of the Atlantic Wolffish, a closely related species. Templeman (1984, 1986) investigated the species' length at maturity, spawning season, fecundity, diet and movements. The biology of this species has also been studied by Simpson and Kulka (2002). A study program on the biology of the Atlantic Wolffish and Spotted Wolffish is currently under way in Quebec (see Dutil *et al.* 2010, Lachance *et al.* 2010, Larocque *et al.* 2008). Laboratory studies have also been done by Falk-Petersen *et al.* (1994). A summary of the biology of wolffish is presented in Kulka *et al.* (2007a) and Simpson *et al.* (2011).

Life Cycle and Reproduction

In the waters off Newfoundland and Labrador, Templeman (1986) determined that sexual maturity in female Spotted Wolffish began at sizes of 75 to 80 cm, that the size at which 50% of females reached sexual maturity (L50) was over 81 cm, and that almost all were mature at sizes greater than 92 cm. The age at maturity (A50) is approximately between 5 and 6 years (Simpson *et al.*, 2011).

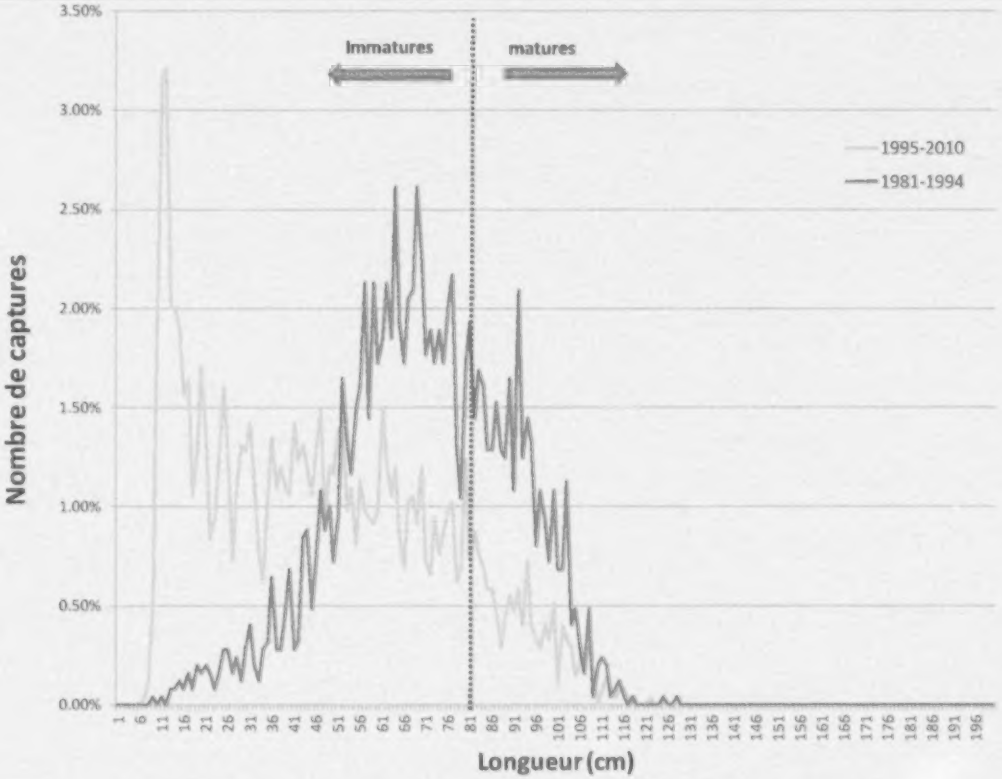
It should be emphasized that some population parameters of the Spotted Wolffish were estimated by Templeman on the basis of specimens caught between 1946 and 1967. Age and size at maturity can be affected by individual condition, water temperature, growth rate and fishing pressure. There are no recent estimates for these parameters.

Spawning is thought to occur primarily in summer (Templeman 1986, Simpson *et al.* 2011). Fertilization is internal (Falk-Petersen *et al.* 1994) and the eggs are likely to be deposited in masses on the bottom (O'Dea and Haedrich 2001), based on observations of Atlantic Wolffish.

Spotted Wolffish are iteroparous. Females produce a relatively small number of eggs. Egg counts for a female 65 cm long caught west of Greenland and a female 91 cm long from the Labrador Sea were 5,080 and 19,760, respectively (Templeman 1986). It is believed that egg survival may be high because the eggs are large (2.5 - 3.5 mm) (Templeman 1986). They are probably also guarded by the male until they hatch, as is the case with Atlantic Wolffish (Keats *et al.* 1985).

Laboratory studies have shown that Spotted Wolffish can hybridize with Atlantic Wolffish, a closely related species (Gaudreau 2009). However, no studies have been conducted on their potential for hybridization in the wild. This is possible given that the ranges of the two species overlap. The occurrence of hybrids has been proposed by Luhmann (1954) on the basis of morphological characters. In addition, Templeman (1986) described a rare spotted form of Northern Wolffish that, in his opinion, could have been a hybrid between Northern and Spotted Wolffish.

Eggs hatch after 800 to 1000 degree-days. Newly hatched larvae are 20 - 24 mm long (Falk-Peterson and Hansen 2003). They likely remain close to the bottom until the yolk sac is absorbed. Growth is probably rapid in the first year, slowing as the fish mature. The maximum reported size is 180 cm (Robins and Ray 1986), although fish > 120 cm are rarely observed in the northwest Atlantic (Figure 10).



Translation of text in figure:
Number of catches
Length (cm)

Note: Differentiation between mature and immature individuals (81 cm) was established on the basis of the lower interval of the size class at which 50% (L50) of the females reached maturity in Templeman (1986).

Figure 10. Length frequency of Spotted Wolffish based on raw catch data from Newfoundland & Labrador fall research trawl surveys from 1981-1994 and 1995-2010. Source: raw data provided by Mark Simpson (pers. comm. 2012).

Generation time is defined by COSEWIC as the average age of parents of the current cohort:

$$G = A + 1/M$$

where A is age at 50% maturity of females and M is the instantaneous rate of natural mortality. A value of A of 5.5 years has been reported above and an assumed M value for a fish that can reach a maximum age around 20 years would generally be 0.2. Generation time would then be approximately 10.5 years.

Physiology and Adaptability

The Spotted Wolffish tolerates temperatures from -1°C to 7°C (Beese and Kandler 1969). Further information is provided in the section on Biology. Its salinity preferences are not known.

Dispersal and Migration

Spotted Wolffish undertake limited movements. Templeman (1984) reported the results of a tagging study between 1962 and 1966 on the three species of wolffish. Of 81 Spotted Wolffish that were tagged, 6 specimens were recaptured, mostly close to the original tagging site (8 km on average, all wolffish species combined). Short migrations have also been observed in the eastern Atlantic (several studies cited in Templeman 1984) and off West Greenland (Riget and Messtorff 1988). However, some movements over large distances (> 800 km) have occasionally been observed for Wolffish in the Northwest Atlantic (Templeman, 1984).

Egg dispersal is unlikely because the eggs are probably deposited on the bottom (O'Dea and Haedrich 2001). However, wolffish (possibly spotted) larvae and young juveniles are found in the upper water column where dispersal can take place.

Interspecific Interactions

According to Templeman (1986), the Spotted Wolffish feeds primarily on echinoderms (52% of its diet by volume), fish (23%) and crustaceans (16%). The main echinoderms consumed are urchins, sand dollars and brittle stars. This indicates that the species feeds on the bottom. More recent data also support the importance of invertebrates (mostly shrimp and echinoderm) in Spotted Wolfish diets (Simpson *et al.* 2011.).

There is little information on the predators of Spotted Wolffish. Juvenile wolffish have been found in the stomachs of Harbour Seals, *Phoca vitulina* (Andersen *et al.* 2004). Although wolffish generally account for only a small fraction of the diet of seals, it is estimated that four seal species — Harp Seal (*Pagophilus groenlandicus*), Hooded Seal (*Cystophora cristata*), Grey Seal (*Halichoerus grypus*) and Harbour Seal — consumed close to 6000 t of wolffish in 1996 in the Canadian Atlantic (Hammill and Stenson 2000). The Harp Seal is the most significant predator because of its high abundance. Wolffish have also been found in the stomachs of Atlantic Cod (Saemundsson 1949 *in* McRuer *et al.* 2000) and Atlantic Halibut (Denis C. pers. comm. 2010). However, Simon and Cook (2011) reported that no Spotted Wolffish were found in the stomachs of over 150,000 fish examined from the Maritime Region.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Changes in Spotted Wolffish abundance were assessed using data from DFO research trawl surveys (Table 2). These surveys, some of which have been conducted for over 40 years, use a stratified random sampling protocol. Taken together, they cover a large range of demersal species in Canada (and even some international areas in Division 3LNO). Essentially, only coastal areas are not covered by the research surveys. There are sporadic surveys for Baffin Bay (NAFO Subarea 0A) in 1999, 2001, 2004, 2006, and 2008 and in Davis Strait (Subarea 0B) in 2000 and 2001.

Table 2. Description of research surveys used in this report to determine Spotted Wolffish abundance trends.

Survey	NAFO Division	Year	Gear
Department of Fisheries and Oceans Canada research trawl surveys			
Summer survey (Maritimes)	4V, 4W and 4X	1970–1981 1982 to present	Yankee 36 trawl Western IIA trawl
Northern Gulf survey	4RS and deep areas of 4T	1990–2003 2004 to present	URI 81'/114 trawl Campelen trawl
Southern Gulf survey	4T	1971–1985 1986 to present	Yankee 36 trawl Western IIA trawl
Spring surveys (Newfoundland & Labrador)	3N, 3O, 3Ps and 3L	1971–1982 1983–1995 1996 to date	Yankee 41.5 trawl Engel trawl Campelen trawl
Fall surveys (Newfoundland & Labrador)	2G, 2H, 3N, 3O, 3K and 3L	1977–1994 1995 to present	Engel trawl Campelen trawl

Survey results are extrapolated to the entire area covered and presented as "minimum trawlable abundance" estimates. These estimates underestimate the actual abundance of the population because the fishing gear does not capture all fish in the trawl area. Some may avoid or escape from the trawl or occur in areas unreachable by the trawl (e.g., very deep areas).

DFO has conducted Newfoundland and Labrador spring and fall research trawl surveys on the Grand Banks, off Newfoundland and in the Labrador Sea since the early 1970s. There have been vessel and gear changes over the course of these surveys (Table 2). The gear change in 1995 has led to the capture of more small fish (<20 cm) (Figure 10).

In addition, the area and depth of coverage has varied in some locations. Similarly, some areas are not surveyed in some years. Table 3 indicates the NAFO Divisons and Subdivisions surveyed from 1971 to 2010.

Table 3. NAFO Subdivisions sampled in DFO Newfoundland & Labrador spring and fall research trawl surveys (dark boxes indicate that a survey was conducted; white boxes indicate no survey).

Year	NAFO Division										
	Fall research trawl survey							Spring research trawl survey			
	2G	2H	2J	3K	3L	3N	3O	3L	3N	3O	3Ps
1971								■	■	■	
1972								■	■		■
1973								■	■	■	■
1974								■	■		■
1975								■	■	■	■
1976								■	■	■	■
1977			■	■				■	■	■	■
1978	■	■	■	■				■	■	■	■
1979	■	■	■	■				■	■	■	■
1980			■	■				■	■	■	■
1981	■	■	■	■	■			■	■	■	■
1982			■	■	■			■	■	■	■
1983			■	■	■						■
1984			■	■	■			■	■	■	■
1985			■	■	■			■	■	■	■
1986			■	■	■			■	■	■	■
1987	■	■	■	■	■			■	■	■	■
1988	■	■	■	■	■			■	■	■	■
1989			■	■	■			■	■	■	■
1990			■	■	■	■	■	■	■	■	■
1991	■	■	■	■	■	■	■	■	■	■	■
1992			■	■	■	■	■	■	■	■	■
1993			■	■	■	■	■	■	■	■	■
1994			■	■	■	■	■	■	■	■	■
1995			■	■	■	■	■	■	■	■	■
1996	■	■	■	■	■	■	■	■	■	■	■
1997	■	■	■	■	■	■	■	■	■	■	■
1998	■	■	■	■	■	■	■	■	■	■	■
1999	■	■	■	■	■	■	■	■	■	■	■
2000			■	■	■	■	■	■	■	■	■
2001		■	■	■	■	■	■	■	■	■	■
2002			■	■	■	■	■	■	■	■	■
2003			■	■	■	■	■	■	■	■	■
2004		■	■	■	■	■	■	■	■	■	■
2005			■	■	■	■	■	■	■	■	■
2006		■	■	■	■	■	■	■	■	■	
2007			■	■	■	■	■	■	■	■	■
2008		■	■	■	■	■	■	■	■	■	■
2009			■	■	■	■	■	■	■	■	■
2010								■	■	■	■

Research trawl surveys began in 1970 in the Scotian Shelf and Bay of Fundy (NAFO Divisions 4VWX, Maritimes summer research trawl surveys). There was a gear change in 1982, when the Yankee 36 was replaced by the Western IIa trawl. These changes may affect catch rates.

DFO conducts two research trawl surveys in the Gulf of St. Lawrence, one covering Divisions 4R, 4S and the Esquiman Channel in Division 4T (northern Gulf research trawl survey) and the other in Division 4T (southern Gulf research trawl survey).

For the northern Gulf research trawl survey, the vessel CCGS *Alfred Needler* equipped with a URI 81'/114' bottom trawl was used from 1990 to 2003. It was replaced by the CCGS *Teleost* equipped with a shrimp trawl. In the southern Gulf, the research trawl survey has been conducted in September since 1971. A gear change from the Yankee 36 to the Western IIA occurred in 1985.

Abundance

Spotted Wolffish abundance estimates from DFO research trawl survey data are in Table 4. The total number of Spotted Wolffish (mature and juveniles) in Canadian waters is estimated to exceed 5 million (see Table 4 for details on evaluation years and areas). This is a conservative estimate, given that the surveys do not catch all individuals in the trawl area, some zones are not covered (e.g., rock bottoms) and abundance estimates are not available in some low-abundance regions, such as the Canadian Arctic. Actual abundance is therefore much higher. According to the combined survey estimates, the abundance of mature Spotted Wolffish exceeds 0.59 million.

Table 4. Minimum trawlable abundance of Spotted Wolffish (total and mature population) in each NAFO Division based on Fisheries and Oceans Canada research trawl surveys. Mature individuals are defined as > 81 cm in length.

NAFO Division	Total Abundance[1] (millions)	Abundance of Mature Individuals (millions)	Survey
2G	0.16[2] [1999]	0.03	
2H	0.40[2] [2008]	0.05	
2J	0.82[2] [2009]	0.07	
3K	1.66[2] [2009]	0.15	Newfoundland & Labrador fall survey
3L	1.50[2] [2009]	0.135	
3N	0.17[2] [2009]	0.02	
3O	0.003[2] [2009]	< 0.000	
3Ps	0.01[2] [2010]	0.002	Newfoundland & Labrador spring survey
4VWX	Very low	Very low	Maritimes summer survey
4RST	0.33[3]	0.13	Northern Gulf summer survey
Total	>5.05	>0.59	

[1] The year of the most recent assessment is in square brackets.
[2] Simpson *et al.* (2011).
[3] Johanne Gauthier, pers. comm. 2012

Fluctuations and Trends

Labrador Sea, eastern Newfoundland, Grand Banks and off southern Newfoundland

The maximum abundance of Spotted Wolffish in Canada is concentrated in the southern Labrador Sea and off northern and eastern Newfoundland (Division 2J3KL). The trends observed in this part of its range are largely indicative of the status of the species.

Spotted Wolffish abundance indices in areas bordering Newfoundland and Labrador (NAFO Divisions 2JKL, 3LNO and 3Ps) declined sharply from the late 1970s to the mid-1990s. However, since 1996, there has been a substantial rebound (Figure 11).

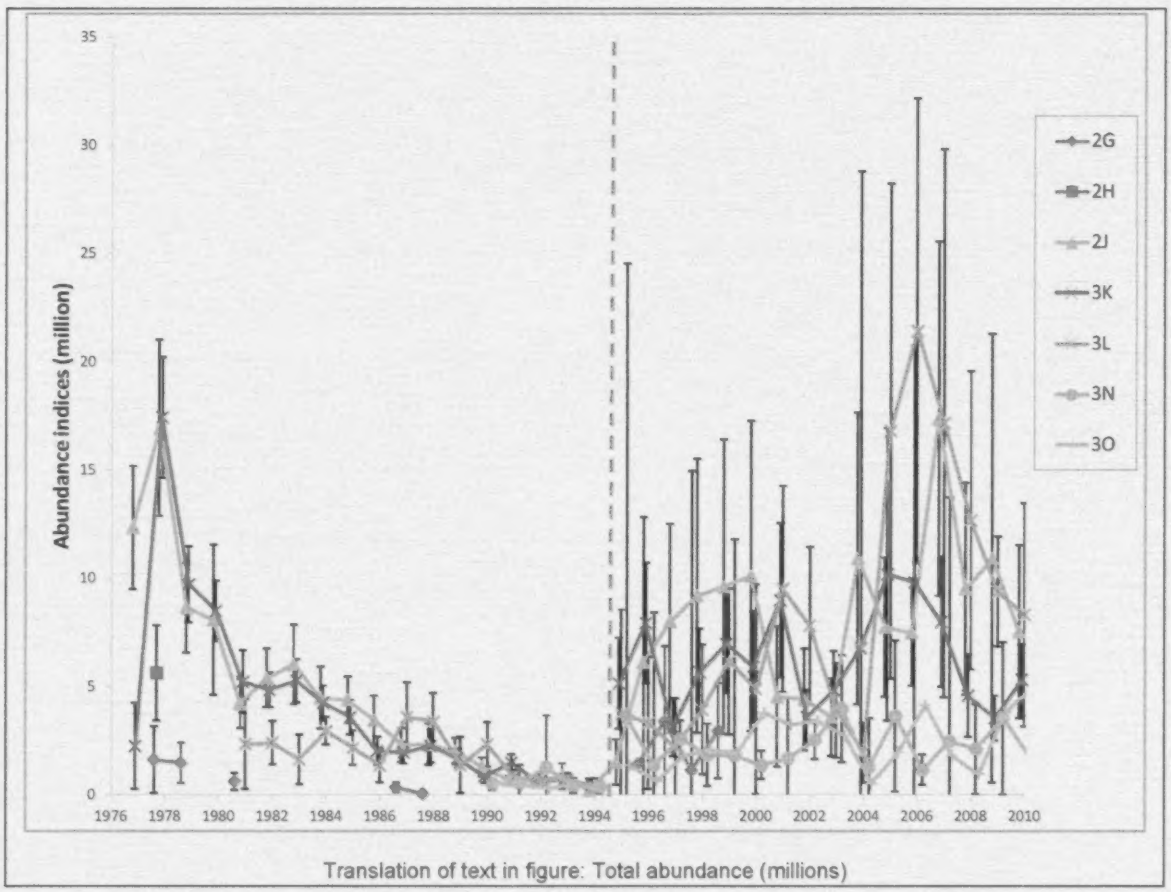


Figure 11. Spotted Wolffish abundance (± CI) estimates based on Newfoundland and Labrador fall research trawl surveys for each NAFO Division covered. The vertical line indicates a change in survey gear. Source: Mark Simpson pers. comm. 2012.

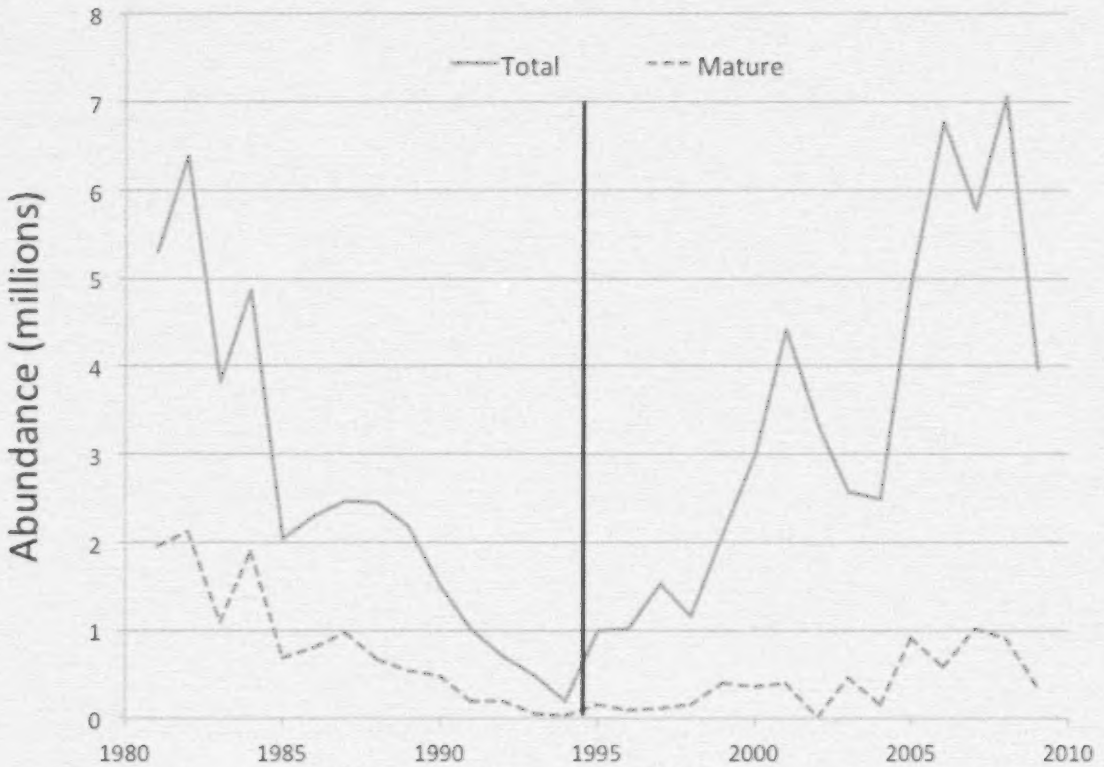


Figure 12. Spotted Wolffish abundance estimate based on Newfoundland and Labrador fall research trawl surveys for NAFO Divisions 2J3KL from 1981 to 2010. The vertical line indicates a change in survey gear. Fish ≥ 81 cm are considered mature. Source: Mark Simpson, pers. comm. 2012.

Abundance estimated from the fall research trawl survey declined in the first half of the time series (1981-1994) in NAFO Divisions 2J3KL (southern Labrador Sea, east of Newfoundland and northern Grand Banks), where the highest abundances are found (Table 5, Figures 11 and 12). In this region, the abundance indices fell from 6.39 million in 1982 to 0.19 million in 1994, a decline of 97% for the mature population (Table 6 and Figure 13). In more northern areas (NAFO Divisions 2GH), data are more sporadic, but they also showed a major decline in abundance from the 1970s to the mid-1990s (Table 5). However, there has been a significant upward trend since 1996 in 2J3KL from 0.15 million adults in 1995 to a maximum of 0.90 million in 2008 followed by a decline to 0.59 million in 2009 (Table 5). This represents an increase of 560% for the mature population (Table 6, Figure 13). It is important to bear in mind that gear changes were made in 1995 and that the two series (1977-1995 and 1996-2009) cannot be compared directly.

Table 5. Spotted Wolffish abundance indices based on Newfoundland and Labrador fall research trawl survey data from the Labrador Shelf.

YEAR	ABUNDANCE INDEX (MILLIONS)*								
	2G	2H	2J	3K	3L	3N	3O	2J3KL	Mature 2J3KL**
1977			2.65	0.00					
1978	0.74	1.07	2.28	2.07					
1979	0.34	1.12	2.02	1.70					
1980			2.46	1.30					
1981	0.50	1.14	1.19	1.02	3.10			**5.30**	**1.96**
1982			2.40	1.06	2.93			**6.39**	**2.12**
1983			1.51	1.38	0.93			**3.83**	**1.10**
1984			1.34	1.07	2.45			**4.86**	**1.90**
1985			0.61	0.52	0.91			**2.04**	**0.68**
1986			0.81	0.70	0.80			**2.31**	**0.82**
1987	0.04	0.30	0.45	0.60	1.43			**2.47**	**0.98**
1988	0.04	0.37	0.58	0.72	1.15			**2.45**	**0.66**
1989			0.58	0.69	0.91			**2.18**	**0.55**
1990			0.26	0.36	0.88	0.01	0.00	**1.51**	**0.49**
1991	0.03	0.06	0.14	0.51	0.36	0.05	0.00	**1.01**	**0.19**
1992			0.20	0.25	0.26	0.05	0.00	**0.71**	**0.19**
1993			0.16	0.09	0.23	0.05	0.00	**0.49**	**0.05**
1994			0.07	0.04	0.09	0.07	0.00	**0.19**	**0.04**
Research Gear Change									
1995			0.08	0.41	0.50	0.24	0.02	**1.00**	**0.15**
1996	0.37	0.17	0.37	0.46	0.18	0.07	0.01	**1.01**	**0.08**
1997	0.23	0.16	0.40	0.62	0.51	0.26	0.01	**1.53**	**0.11**
1998	0.03	0.27	0.14	0.47	0.55	0.10	0.02	**1.15**	**0.16**
1999	0.16	0.21	0.22	1.17	0.72	0.18	0.03	**2.11**	**0.08**
2000			0.26	1.72	1.03	0.17	0.00	**3.01**	**0.11**
2001		0.04	0.19	1.95	2.28	0.02	0.01	**4.42**	**0.16**
2002			0.20	0.72	2.42	0.36	0.05	**3.34**	**0.41**
2003			0.35	1.28	0.94	0.12	0.05	**2.56**	**0.36**
2004		0.51	0.76	1.43	0.30	0.03	0.01	**2.48**	**0.40**
2005			0.63	1.78	2.55	0.15	0.02	**4.96**	**0.00**
2006		0.46	0.51	2.55	3.73	0.15	0.01	**6.79**	**0.47**
2007			0.96	2.30	2.52	0.06	0.06	**5.78**	**0.16**
2008		0.40	1.39	2.79	2.89	0.17	0.02	**7.07**	**0.90**
2009			0.82	1.66	1.50	0.17	0.00	**3.97**	**0.59**

*Blanks indicate that no survey was conducted.
** Abundance of mature is based on the proportion of fish ≥ 81.0 cm.

Table 6. Rate of change details for Spotted Wolffish abundance indices based on research trawl survey data.

Survey	NAFO Divisions	Years	Total/mature	Rate of change (%)	Natural log regression parameters			
					N	R2	P-values	Slope
Newfoundland & Labrador Fall Survey	2J3KL S. Labrador Shelf	1981-1994	Total	-94	13	0.86	< 0.001	-0.219
			Mature	-97	13	0.85	< 0.001	-0.283
		1995-2009	Total	527	14	0.77	< 0.001	0.131
			Mature	560	14	0.58	0.001	0.135
Newfoundland & Labrador Spring Survey	3LNOPs Grand Banks	1971-1982	Total	406	11	0.28	0.040	0.148
		1984-1995	Total	-63	11	0.16	0.175	-0.091
			Mature	-94	11	0.48	0.018	-0.249
		1996-2010	Total	283	14	0.40	0.023	0.096
			Mature	460	14	0.20	0.112	0.123
Northern Gulf	4RST	1990-2009	Total	251	19	0.40	0.006	0.228
		1997-2009	Mature	184	12	0.38	0.034	0.087

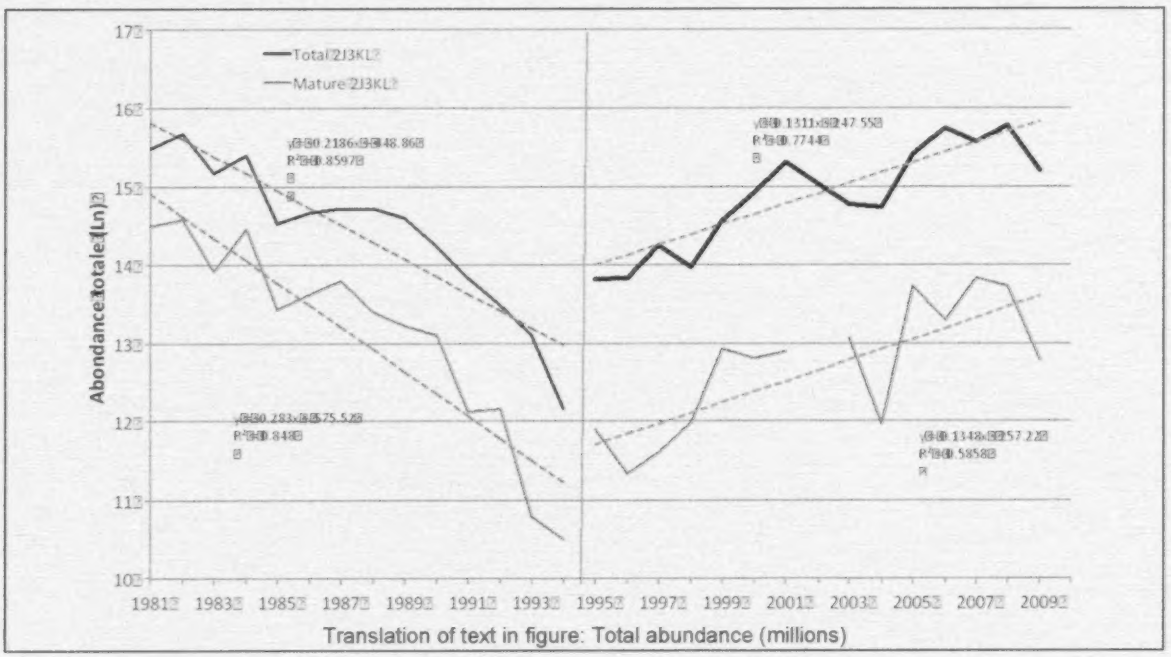


Figure 13. Natural log of Spotted Wolffish abundance estimates based on Newfoundland and Labrador fall research trawl surveys for NAFO Divisions 2J3KL. Fitted regressions are shown. The vertical line indicates a gear change. Fish ≥ 81 cm are considered mature.

In the spring research trawl surveys conducted in Divisions 3LNOPs, the vast majority of catches come from NAFO Division 3L (northern Grand Banks off Newfoundland) (Figure 14). The three data series (1971 to 1982, 1984 to 1995 and 1996 to the present) cannot be compared directly due to the gear changes. An increase of 406% in the total population indices for 3LNOPs was observed from 1971 to 1982, followed by a decline in the 1980s and early 1990s (Table 7, Figures 14 and 15). Abundance indices fell from 0.32 million in 1988 to a low near-zero survey catches in 1994 (Table 7). Since then, abundance has increased considerably such that the values recorded between 2004 and 2007 were by far the highest since the start of the time series in 1996 (Figure 14). Total abundance in Division 3L was estimated at a high of 4.94 million in 2006 compared to a low of 0.33 million in 1997 (minimum). The rates of increase are 283% and 460% for the total and the mature population, respectively, from 1996 to 2010 (Table 6, Figure 15).

Table 7. Spotted Wolffish abundance indices based on Newfoundland and Labrador spring research trawl survey data in the Grand Banks.

YEAR	ABUNDANCE INDEX (MILLIONS)*					
	3L	3N	3O	3Ps	Total	Total mature**
1971	1.68	0.00				
1972	0.24	0.00		0.01		
1973	0.03	0.04	0.00	0.00	**0.07**	
1974	0.50	0.02		0.01	**0.53**	
1975	1.40	0.00	0.00	0.05	**1.45**	
1976	1.09	0.00	0.09	0.01	**1.20**	
1977	1.61	0.05	0.00	0.02	**1.68**	
1978	0.52	0.07	0.01	0.02	**0.63**	
1979	1.44	0.06	0.00	0.00	**1.50**	
1980	1.36	0.07	0.00	0.00	**1.43**	
1981	2.56	0.20	0.00	0.00	**2.76**	**0.77**
1982	1.21	0.03	0.03	0.00	**1.26**	**0.31**
1983	**Research Gear Change**					
1984	0.03	0.04	0.01	0.01	**0.09**	**0.09**
1985	0.38	0.00	0.00	0.03	**0.41**	**0.19**
1986	0.41	0.02	0.00	0.00	**0.43**	**0.20**
1987	0.71	0.00	0.00	0.00	**0.71**	**0.15**
1988	0.80	0.01	0.00	0.02	**0.83**	**0.32**
1989	0.65	0.00	0.02	0.00	**0.67**	**0.20**
1990	0.57	0.02	0.01	0.01	**0.61**	**0.12**
1991	0.10	0.03	0.01	0.00	**0.15**	**0.01**
1992	0.14	0.04	0.00	0.00	**0.18**	**0.03**
1993	0.12	0.05	0.00	0.00	**0.17**	**0.01**
1994	0.09	0.01	0.01	0.00	**0.10**	**0.00**
1995	0.07	0.06	0.00	0.00	**0.13**	**0.03**
	Research Vessel Change					
1996	0.54	0.07	0.00	0.00	**0.61**	**0.05**
1997	0.33	0.09	0.01	0.01	**0.44**	**0.02**
1998	0.54	0.14	0.00	0.00	**0.68**	**0.20**
1999	0.60	0.09	0.05	0.02	**0.76**	**0.19**

YEAR	ABUNDANCE INDEX (MILLIONS)*					
	3L	3N	3O	3Ps	Total	Total mature**
2000	1.05	0.06	0.00	0.05	**1.17**	**0.35**
2001	0.88	0.12	0.00	0.04	**1.04**	**0.19**
2002	0.80	0.05	0.00	0.03	**0.89**	**0.02**
2003	0.87	0.09	0.00	0.11	**1.07**	**0.13**
2004	2.10	0.05	0.01	0.02	**2.18**	**0.67**
2005	2.97	0.15	0.00	0.05	**3.17**	**0.54**
2006	4.94	0.00	0.00			
2007	4.40	0.04	0.00	0.00	**4.44**	**0.80**
2008	2.02	0.12	0.02	0.01	**2.17**	**0.60**
2009	0.46	0.06	0.00	0.07	**0.59**	**0.04**
2010	1.85	0.05	0.00	0.01	**1.92**	**0.36**

*Blanks indicate that no survey was conducted.
** Abundance of mature is based on the proportion of fish ≥ 81.0 cm.

Arctic, Gulf of St. Lawrence, Scotian Shelf

In the northern part of its Canadian range (Baffin Bay and Davis Strait), available data and catch rates are insufficient to establish the status of this species.

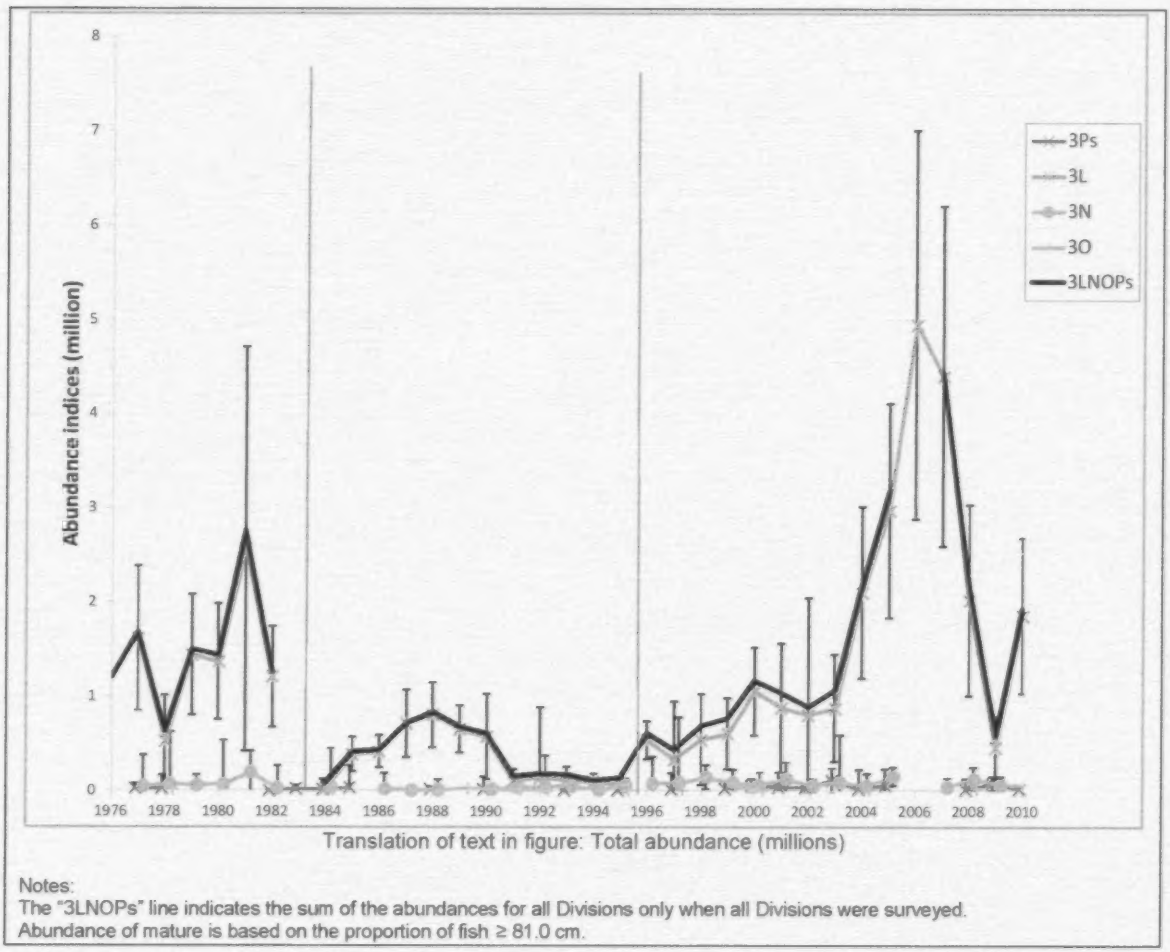
In the rest of its Canadian range, Spotted Wolffish abundance is relatively low (Table 6). In the Gulf of St. Lawrence, the Spotted Wolffish is rare in DFO research trawl survey catches. However, abundance indices show an increasing trend since the early 1990 (Table 8, Figures 16 and 17). Indices rose from almost no catch in 1994 to over 0.3 million individuals in 2009. In NAFO Division 4T, Spotted Wolffish has been captured only in 26 years out of 40 from 1971 to 2010 in Southern Gulf Research Surveys (Benoit, H. pers. comm. 2012).

Table 8. Spotted Wolffish abundance indices based on the Northern Gulf summer research trawl survey data (4RST).

YEAR	ABUNDANCE INDEX (MILLION)	
	Total	Mature (>81 cm)
1990	0.07	0.00
1991	0.00	0.00
1992	0.00	0.00
1993	0.00	0.00
1994	0.00	0.00
1995	0.05	0.00
1996	0.05	0.00
1997	0.08	0.06
1998	0.06	0.02
1999	0.13	0.13
2000	0.15	0.05
2001	0.00	0.00
2002	0.10	0.05
2003	0.16	0.10
2004	0.73	0.16
2005	0.25	0.13

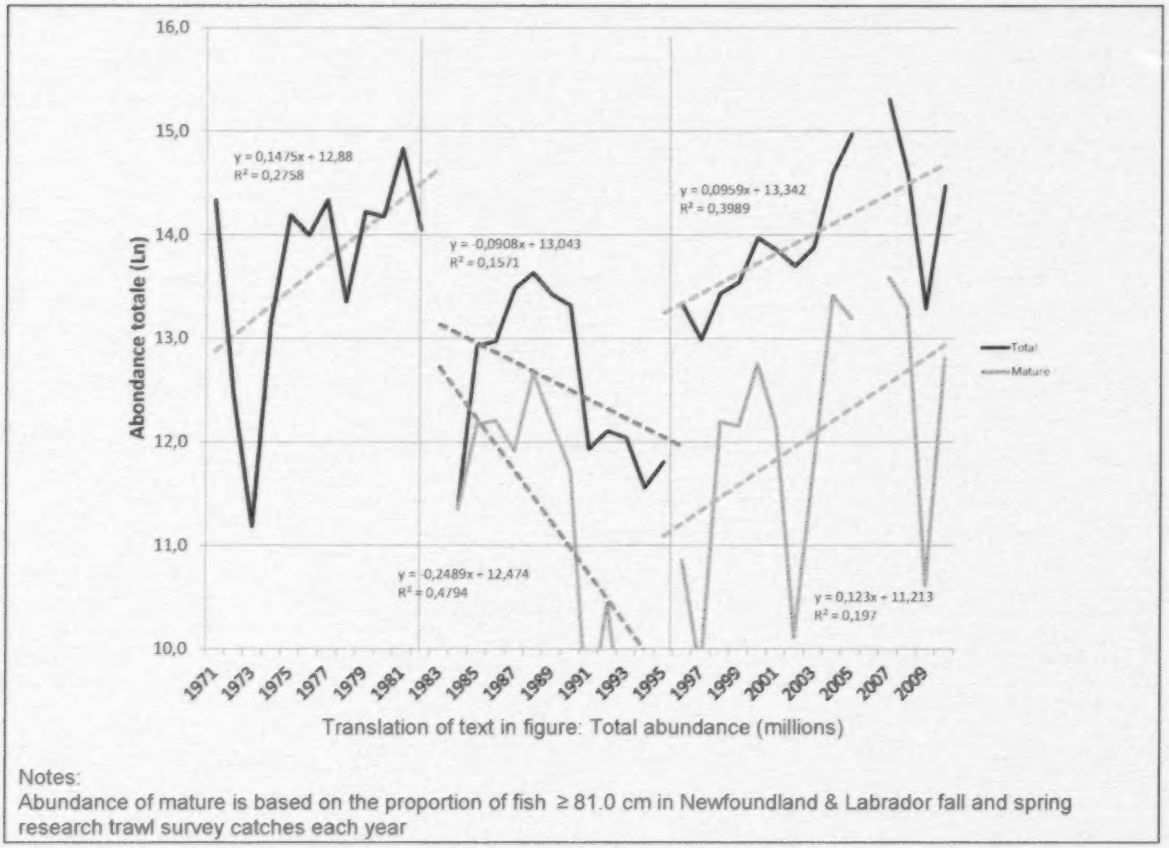
YEAR	ABUNDANCE INDEX (MILLION)	
	Total	Mature (>81 cm)
2006	0.32	0.14
2007	0.17	0.07
2008	0.46	0.13
2009	0.33	0.13

Source: Bourdage and Ouellet, in preparation.



Notes:
The "3LNOPs" line indicates the sum of the abundances for all Divisions only when all Divisions were surveyed.
Abundance of mature is based on the proportion of fish ≥ 81.0 cm.

Figure 14. Spotted Wolffish abundance (± CI) estimate based on Newfoundland and Labrador spring research trawl surveys for each NAFO Division covered. The vertical lines indicate gear changes.



Notes:
Abundance of mature is based on the proportion of fish ≥ 81.0 cm in Newfoundland & Labrador fall and spring research trawl survey catches each year

Figure 15. Natural log of Spotted Wolffish abundance estimate based on Newfoundland and Labrador spring research trawl surveys for NAFO Division 3LNOPs. Fitted regressions are shown. The vertical lines indicate gear changes.

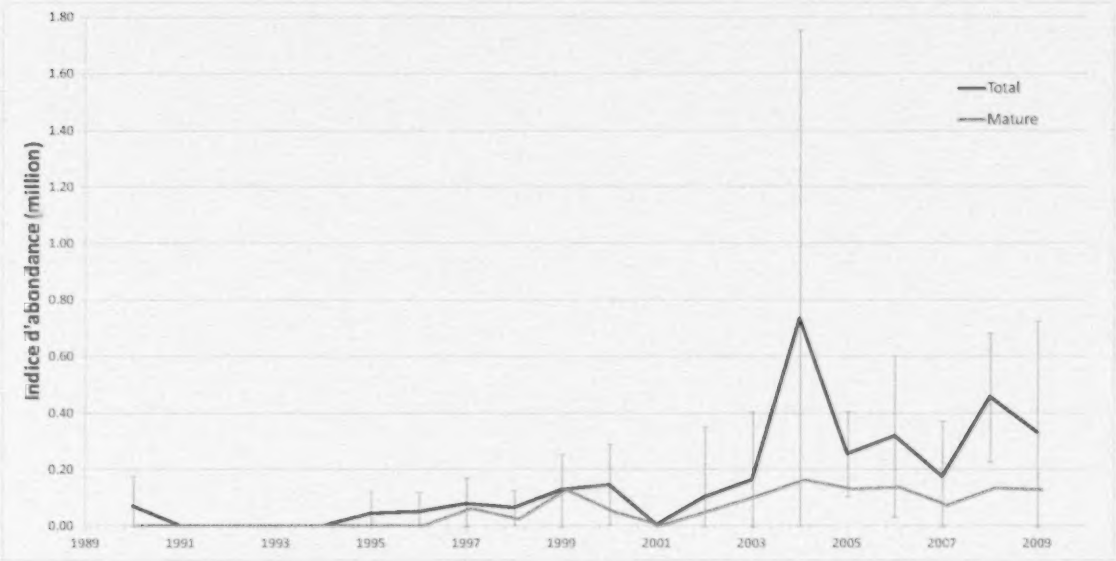


Figure 16. Spotted Wolffish abundance estimates (± CI) based on Northern Gulf summer research trawl surveys (NAFO Divisions 4RST). Source: Bourdage and Ouellet (in prep.).

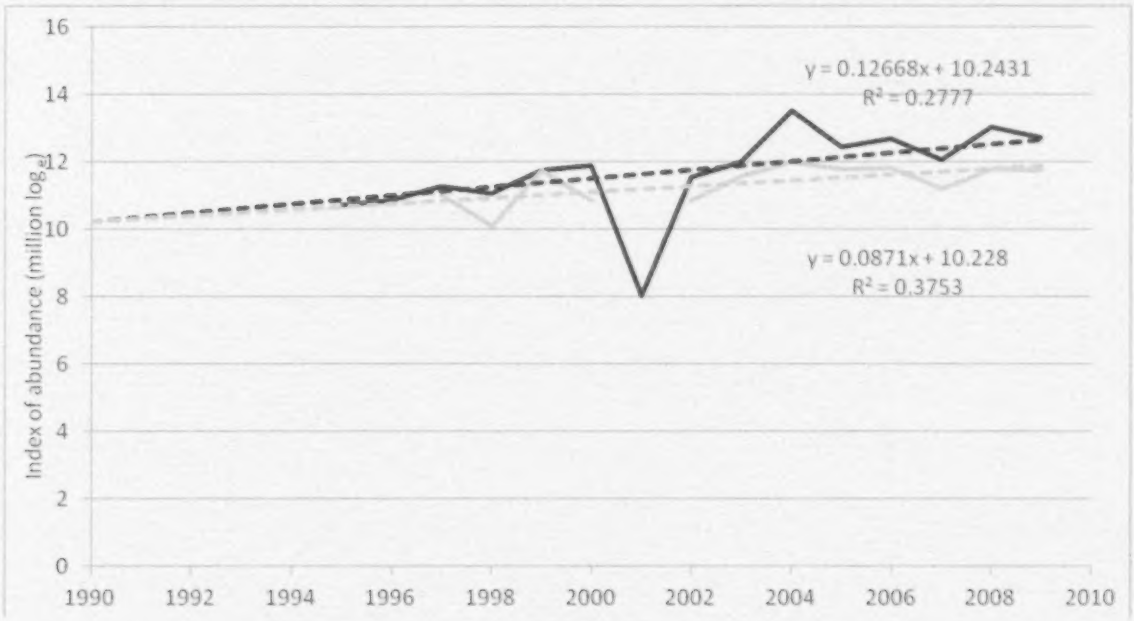


Figure 17. Natural log of Spotted Wolffish abundance estimate based on Northern Gulf summer surveys (NAFO Divisions 4RST). Fitted regressions are shown for mature individuals (blue) and total individuals (black).

In the Maritimes summer research trawl survey, which essentially covers the Scotian Shelf, the species has been caught in only 22 of a total of 7200 tows since 1970. Therefore, the abundance trend in this region cannot be evaluated.

Trend Summary for Canada

Overall, this species underwent strong declines from the late 1970s until the mid-1990s, but since then there has been an increase from their low numbers over most of the Canadian range. Differences among regions in survey methods and changes in gear over time preclude formal calculations of an overall trend for this species in Canada. However, a general indication is needed to assess this species' overall status. We can get a rough approximation by weighting the rates of change of each area by the number of fish in that area at the start of its time series.

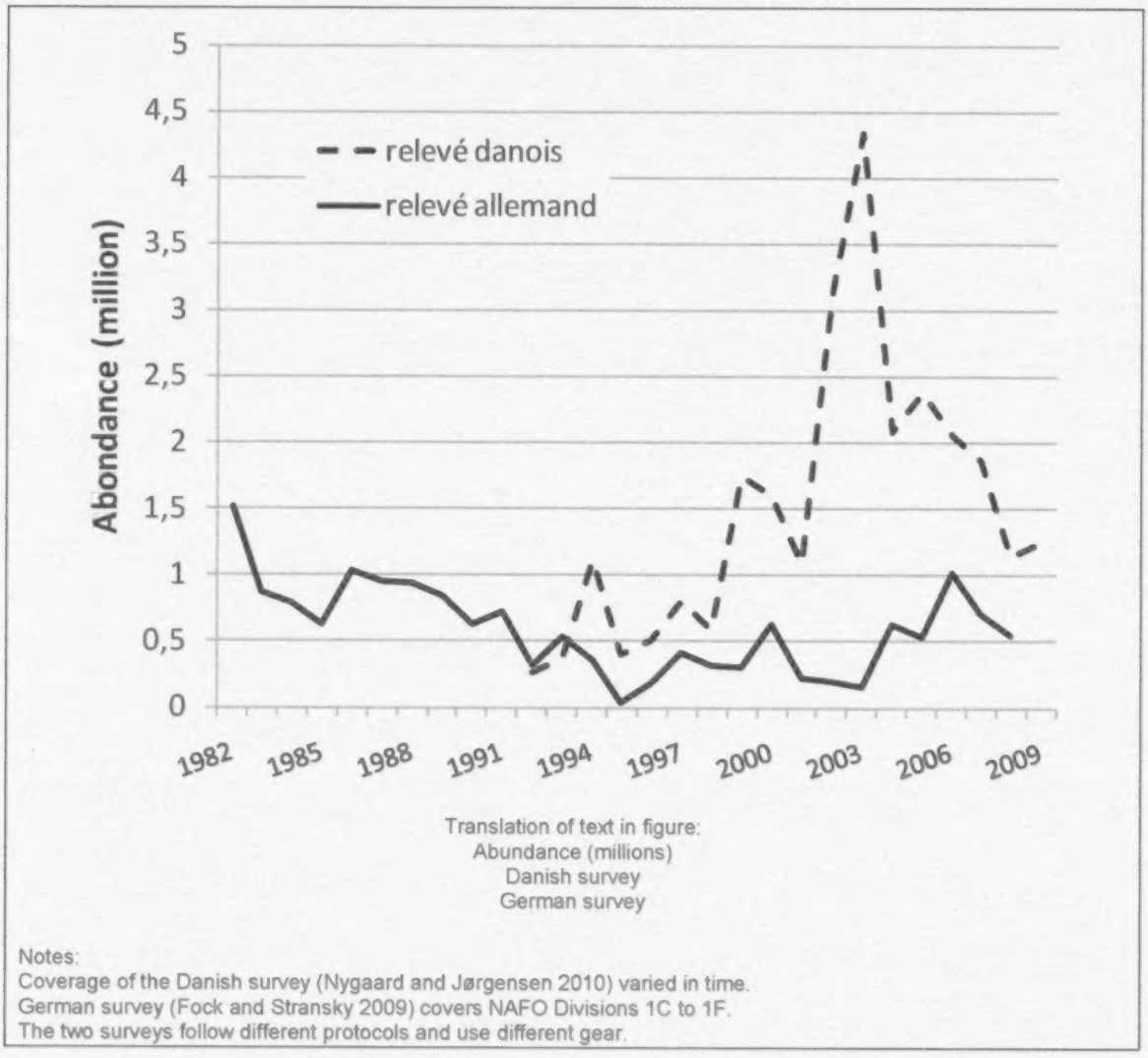
The southern Labrador Shelf (2J3KL) was the historical stronghold, with about 1.7 million mature individuals over the first three years of the time series, and these fish declined by about 97% up to the time of the gear change in the mid-1990s (Table 6). Although the new gear probably has higher catchability, we can account for this to some extent by multiplying the 3% of fish that remained prior to the gear change by their rate of increase afterward, which brought them to about 20% of their original numbers. Taken together, this suggests an overall decline of about 80%. Fish on the Grand Banks (3LNOPs) historically numbered only around 160,000, and they declined in the first half of the time series by about 94%. The remaining 6% of the population then increased after the gear change in the mid-1990s to about 25% of the original number. Again, note the caveat about higher catchability of the gear. Taken together, this suggests an overall decline of about 75%, which is similar to the decline in the southern Labrador Shelf. Thus, the overall rate of decline for these two regions combined has been about 75-80%. It should be emphasized that these are back-of-the-envelope calculations, intended only to give a general impression of the magnitude of decline relative to the ranges that are used by IUCN criteria.

Rescue Effect

The range of the Spotted Wolffish extends outside Canadian waters and it is likely that fish along international boundaries belong to the same population as those in Canadian waters.

This species is distributed to the south, in the Gulf of Maine and on the Georges Bank (rare); to the north, off West Greenland; and to the east, in several NAFO Divisions that are partially (Divisions 3NO) or entirely (3M) located in international waters (Figure 2). Rescue from the south is very unlikely, given the rarity of the species there.

Based on a Northern Shrimp (*Pandalus borealis*) research survey by a Danish team (Nygaard and Jørgensen 2010), Spotted Wolffish abundance off West Greenland (adjacent to the northern part of its Canadian range) was estimated at 1.2 million in 2010. The abundance indices increased from the start of the survey in 1992 to 2003, when maximum values were recorded (4.3 million), but have since trended downward (Figure 18). According to another trawl survey conducted by a German research institute in NAFO Divisions 1C to 1F, Spotted Wolffish abundance indices have generally increased since the early 2000s (Fock and Stransky 2009) (Figure 18). Abundance in this region was estimated at 0.5 million in 2008.



Notes:
Coverage of the Danish survey (Nygaard and Jørgensen 2010) varied in time.
German survey (Fock and Stransky 2009) covers NAFO Divisions 1C to 1F.
The two surveys follow different protocols and use different gear.

Figure 18. Spotted Wolffish abundance indices based on two surveys conducted west of Greenland.

On the basis of surveys by the Spanish Institute of Oceanography (Gonzáles-Troncoso and Paz 2007), Spotted Wolffish abundance on the Flemish Cap (NAFO Division 3M), east and adjacent to Canadian (Grand Bank) waters was estimated at over 2.6 million in 2006. Although the abundance index has been declining since 1997, it has remained at values similar to those recorded in the 1980s (Figure 19).

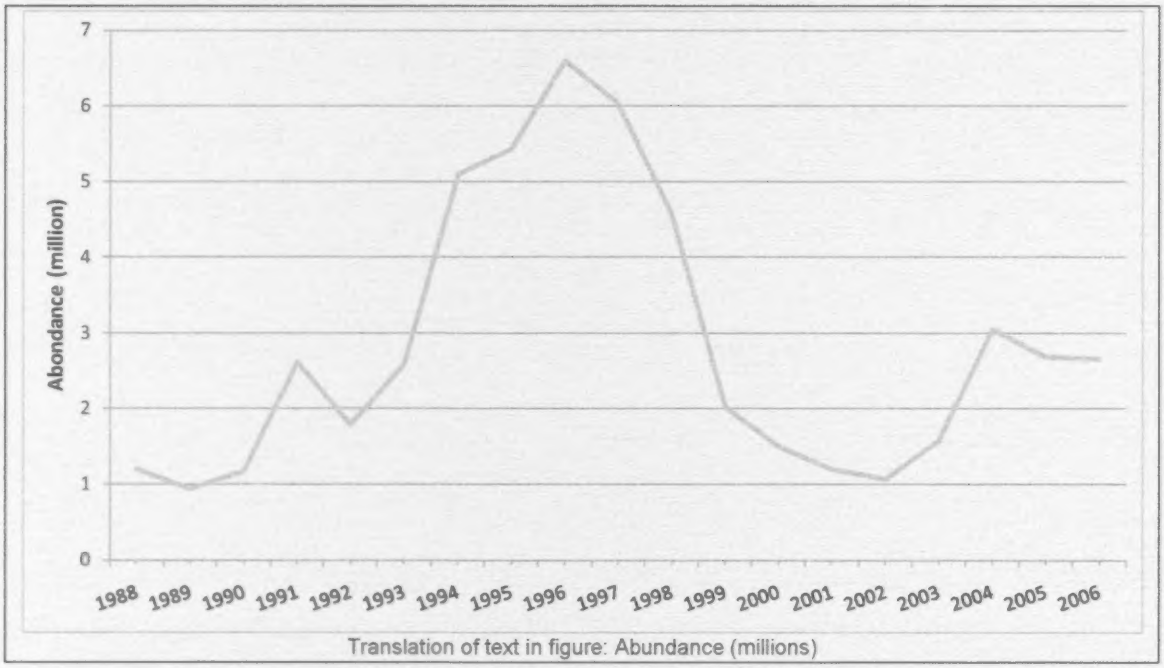


Figure 19. Spotted Wolffish abundance estimates (adult and immature) on the Flemish Cap (NAFO Division 3M) based on research trawl surveys conducted by the Instituto Español de Oceanografía [Spanish institute of oceanography]. Based on Gonzalez-Troncoso and Paz (2007).

Thus, Spotted Wolffish abundance off the coast of Greenland and on the Flemish Cap is relatively high and these regions could provide a source of immigration to Canadian waters. However, only the larval life stage is apt to disperse.

THREATS AND LIMITING FACTORS

Commercial Fishery and Bycatch

Prior to the implementation of the mandatory release policy for threatened wolffish species in 2003, there were no regulations governing wolffish fishing periods or catch levels. Since then the release of catches of Spotted Wolffish (and Northern Wolffish) has been mandatory. They are caught primarily as bycatch in other fisheries and the different species are not differentiated unless vessels have fisheries observers. Therefore the data presented in this report include all landings for all wolffish species combined, as recorded by NAFO (2010) (Figure 20). Note that wolffish discarded at sea (regardless of species) are never reported in NAFO statistics. Furthermore, Canadian fisheries observer data suggest that approximately 1,000 tonnes of wolffish (combined species) were discarded annually in Canadian waters (Subareas 2 and 3) over 1958-1994 and in 1999, and discards declined to < 200 tonnes since 2006 (Simpson *et al.*, 2011).

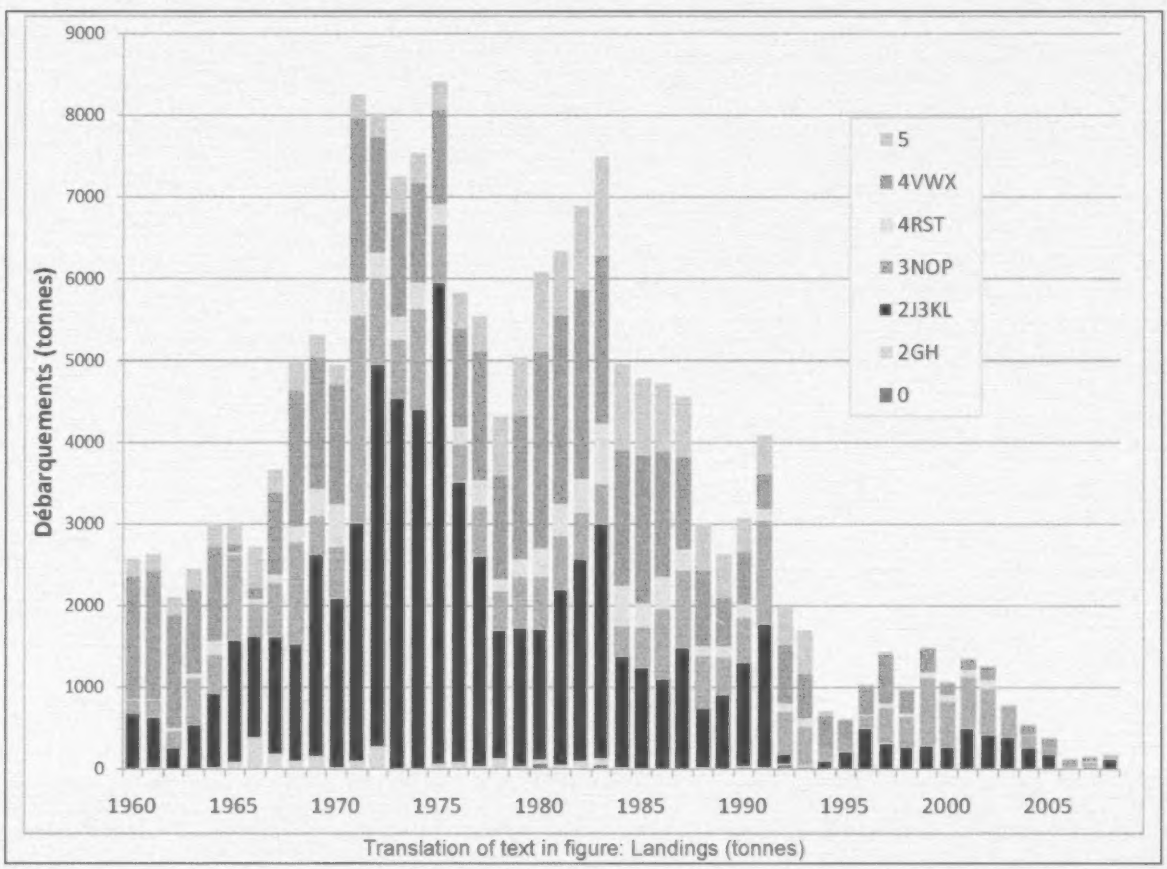


Figure 20. Reported wolffish landings (*Anarhichas lupus*, *A. minor* and *A. denticulatus* combined) in NAFO Divisions located entirely or partly in Canadian waters. Source: NAFO (2010).

Most reported catches come from the Labrador Sea and northeast Newfoundland (NAFO Divisions 2J3KL) and along the southern slope of the Laurentian Channel and Scotian Shelf (4VWX), although the Scotian Shelf catches are likely Atlantic Wolffish. Since the 1990s, a large proportion of catches have been reported from southern Newfoundland and the Grand Banks (3NOP). Records from Shrimp Fishing Areas 0-3 (from east of Baffin Island to waters around the Ungava Peninsula) show that 3-18% of sets catch one or more of this species (depending on the area and year) (Silferd 2010). Wolffish are also fished outside Canadian waters, where catch records do not distinguish between species and discarded wolffish are not recorded.

Commercial log data underreport wolffish catch rates (Kulka *et al.* 2007a). In fact, close to half of Spotted Wolffish bycatch in Canada is believed to be discarded without being reported (Simpson and Kulka 2002). Landed values prior to 2003 therefore underestimate commercial removals from the population. Experiments done on Atlantic Wolffish indicate survival is high if released soon after capture (Grant *et al.* 2005), but such shallow water releases probably underestimate mortality from deeper captures.

Disturbance or alteration of ocean bottoms by repeated use of mobile gear (primarily bottom trawls and dredges) could pose a threat to groundfish.

Due to the significant reduction in Spotted Wolffish catch and fishing effort in general, commercial groundfish fisheries currently pose less of a threat to this species than in the 1970s and 1980s. Fishing was surmised as the main cause of the decline of wolffish species (O'Dea and Haedrich 2001), though Kulka *et al.* (2004) argued that neither bycatch nor the alteration of bottoms was the main or only cause of the decline of the three wolffish species. They suggested that the decline of Spotted Wolffish in unfished areas was as great as or greater than that in heavily fished locations, thereby implicating unknown factors in addition to fishing pressure.

Environmental Variables

An episode of cold temperatures from the late 1980s to 1990 (Colbourne *et al.* 2004) partly coincided with the decline in wolffish species. However, the available data and knowledge are insufficient to state that the decline in wolffish was a direct result of a drop in water temperatures. Indeed, the decline of Spotted Wolffish is evident from the start of research trawl surveys in the early 1980s, before the cold period. It is expected that temperature increases will be more pronounced in Arctic or Subarctic zones where Spotted Wolffish are found (Trenberth *et al.* 2007). As a general rule, movements will be towards the poles (Cochrane *et al.* 2009). Thus, boreal and subarctic species, such as wolffish, could shift northward (Gucinski *et al.* 1990).

Number of Locations

Following IUCN guidelines, COSEWIC defines the number of locations according to the threats. Since the main threat is bycatch in fisheries, this species can be considered to occupy a large number of locations, as the different fisheries occur across a wide geographic area and are managed separately.

PROTECTION, STATUS AND RANKS

Legal Status and Protection

The Spotted Wolffish was first designated as "Threatened" by COSEWIC in 2001, the status was confirmed in 2012, and the species has been protected under the federal *Species at Risk Act* since 2003, which specifies release of all captured individuals. In addition, the *Fisheries Act* prohibits the destruction of habitats of fish that are subject to fisheries, though the extent of such protection to species such as Spotted Wolffish that are not targeted by fisheries, is unclear. The Spotted Wolffish is listed as likely to be designated threatened or vulnerable under Quebec's *Act Respecting Threatened or Vulnerable Species* (Loi sur les espèces menacées ou vulnérables; R.S.Q., c E-12.01). There is no mention of this species in the CITES appendices or the United States *Endangered Species Act*.

Non-Legal Status and Ranks

The species has not been ranked at the global or Canadian level by NatureServe, and is listed as Vulnerable to Apparently Secure (S3S4) by Quebec. It has not been assessed by the International Union for the Conservation of Nature (IUCN).

Habitat Protection and Ownership

In the Canadian portion of the northwest Atlantic there are five small marine protected areas as well as a few other areas closed to trawling. However, the area of protection for Spotted Wolffish is very small compared to its widespread distribution and habitat requirements. The effects of these closures on fish that live in the protected and closed areas are unknown, and their overall impacts on the population are apt to be very limited.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Red Méthot received a Master's degree in Oceanography from the Institut des Sciences de la Mer (ISMER) in 2002. His studies were focused on spatial and temporal aspects of cod reproduction in the context of stock management. Following his studies, he worked for Fisheries and Oceans Canada on fisheries-related projects. The writer works at Golder Associates as an oceanographer and ichthyologist. He is regularly involved in fish population monitoring studies and environmental impact assessments in Canada and abroad.